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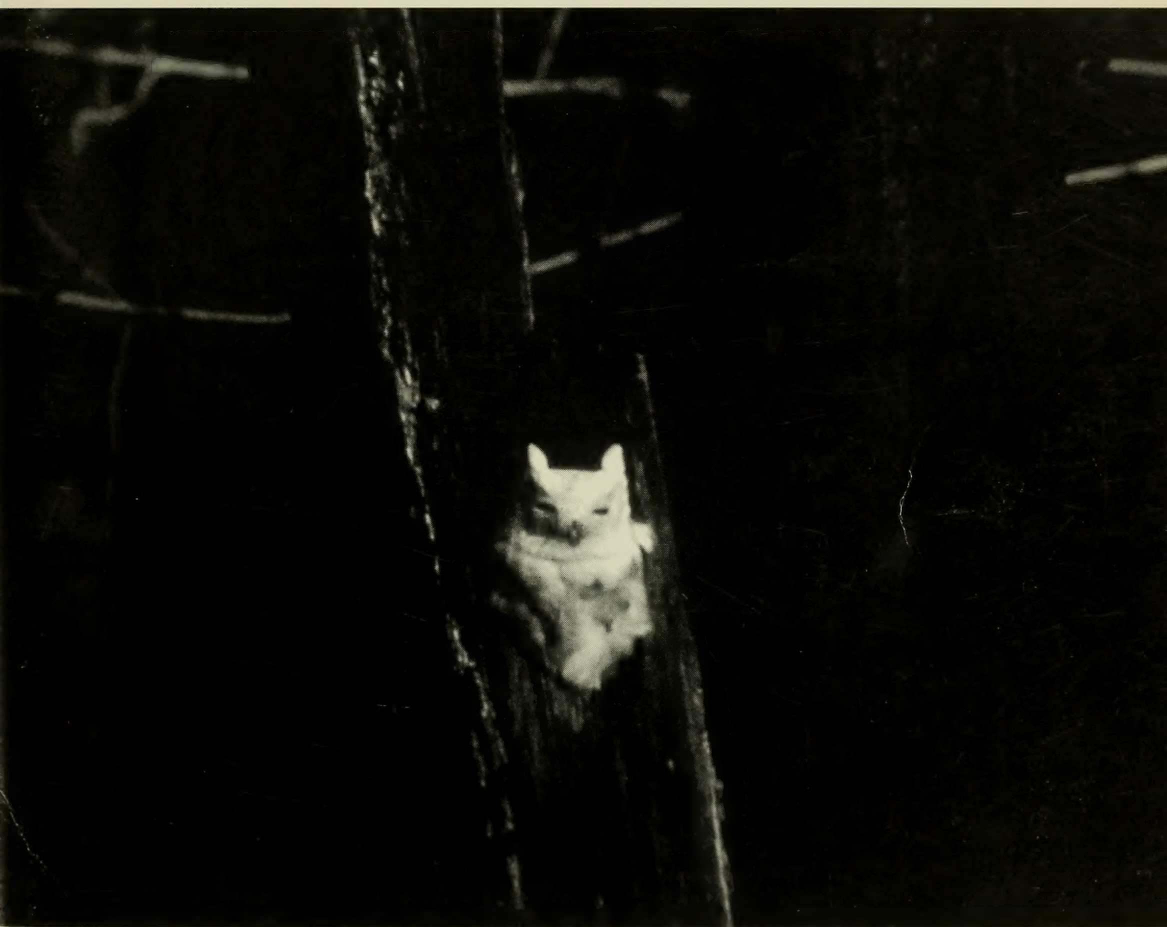

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The Nest and Eggs of the Whooping Crane, *Grus americana*

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Kuyt, E. 1995. The nest and eggs of the Whooping Crane, *Grus americana*. Canadian Field-Naturalist 109(1): 1–5.

In 1966-1991, 500 Whooping Crane (*Grus americana*) nests were examined during annual egg collections on the breeding range in Wood Buffalo National Park, Canada. During this period, 319 eggs and 273 nests were measured and described. Nests were located in stands of emergent vegetation in shallow ponds. Water levels influenced nest height as well as use of emergent nesting cover in high water years (sedge) or low water years (bulrush). Old nests were rarely used in successive years. Clutch size (n = 500) was 2 eggs (90.8%), 1 egg (8.6%) or 3 eggs (0.6%). Eggs in the same clutch did not differ ($P < 0.05$) in length and weight. Novice eggs were narrower and weighed less ($P < 0.05$) than other eggs. Infertile eggs were longer than viable eggs ($P < 0.05$).

Key Words: Whooping Crane, *Grus americana*, Wood Buffalo National Park, nest and egg description, breeding range.

After Bradshaw (1956) recorded a Whooping Crane (*Grus americana*) nest in 1922 near Plenty, Saskatchewan, 33 years passed before the next nest was found by W. A. Fuller in Canada's Wood Buffalo National Park (WBNP). The latter find was made in 1955, a year after G. M. Wilson and D. Landells discovered the nesting area after having sighted unfledged young Whooping Cranes (Allen 1956). At present, WBNP and its immediate vicinity constitutes the only remaining nesting area of this species. Most nesting occurs in the Northwest Territories (N.W.T.) portion of WBNP which lies north of 60° N. Since 1977, 1-4 pairs have nested in the Alberta portion of WBNP (south of 60°N) and the southernmost recorded nest to date, located in 1990, was at 59° 44′N, 113° 20′W (Kuyt 1993).

In 1967, the wild population numbered 43 birds, and the Canadian Wildlife Service (CWS) and the United States Fish and Wildlife Service (USFWS) initiated a cooperative program to increase its numbers. The CWS conducted aerial searches for nesting pairs and annually visited most nest sites to remove eggs. The collected eggs, intended for the establishment of wild or captive populations elsewhere, were transported by air to the USA (Kuyt 1968; Erickson and Derrickson 1981).

This paper summarizes information on nest site characteristics, nesting chronology, clutch size, and egg morphology that I obtained during annual visits in May in 1967-1969, 1971, and 1974-1991, and during incidental visits in 1970, 1972 and 1973. Occasional June visits to nests were made to salvage unhatched or destroyed eggs.

Methods

Whooping Cranes nested in areas inaccessible to ground vehicles or fixed-wing aircraft, and thus helicopters were used to transport personnel and eggs to and from nests. During nest visits, nests and eggs were examined and photographed, egg viability tests conducted, nests measured to the nearest cm (diameter and height above water) and nest pond water depths measured to the nearest cm at 1 m from the nest edge farthest from the nearest shore. One egg (two eggs from 3-egg clutches) was selected at random unless an egg was obviously abnormal in shape (only two or three eggs were so identified). When present, an abnormal egg was removed, leaving the better egg in the nest. The removed egg was then slipped into a woollen sock and carried to the helicopter where it was placed in a portable insulated suitcase (Kuyt 1968; Drewien and Kuyt 1979; Erickson 1981). If both eggs in a nest were non-viable, a live egg from another nest was substituted.

Eggs were transported to Fort Smith, N.W.T., 75–100 km from the nesting area. Eggs were weighed to the nearest 0.5 g on a triple-beam balance, length and width (widest part of egg) measured to the nearest mm, and then placed in electric incubators. Viability tests (Kuyt and Drewien, in preparation) of eggs were performed in the field and repeated at Fort Smith (field tests are sometimes inconclusive) by means of immersion of the egg in a container of 30°-34°C water. These tests indicated whether or not the egg contained a viable embryo, and also the incubation stage. However, incubation

stage was generally known from observed laying dates assessed during aerial surveys.

Nest visits to collect eggs were generally made during the last week in May when most eggs were in the last week of incubation and likelihood of nest desertion was minimal. Nest visitations were brief, average time on the ground at each nest during 388 helicopter landings in 1967-1991 was 9.1 min.

Statistical analyses were performed using Mann-Whitney, Wilcoxon signed rank, G- and t-tests.

Results and Discussion

Nest Description

Whooping Cranes built their nests in the shallow portions of still waters: small lakes, ponds or wet meadows. I found one floating nest in 1967 along the shore of a small creek. Mean water depth of 304 nest ponds, measured in 1976-1991, varied from 14 - 16 cm in low water years to 21 -28 cm when water levels were high. Annual production of juveniles was significantly correlated with yearly mean water depths at nest sites (Kuyt et al. 1992). Most nests were located in emergent vegetation such as Roundstem Bulrush, *Scirpus validus*, or sedge, *Carex aquatilis*, *C. atherodes*, but rarely in cattail, *Typha latifolia*. Occasionally, a nest was built on a natural islet where clumps of willows including *Salix candida*, *S. planifolia*, *S. pedicellaris*, Swamp Birch, *Betula pumila*, and Sweetgale, *Myrica gale*, provided the base of the nest.

Whooping Crane nests and eggs are cryptically coloured and, due to their placement in wetlands and on islets, were relatively inaccessible to terrestrial predators. This strategy seems to work well for Whooping Cranes as I have rarely found nests destroyed by predators. Two unusual nests, built by the same pair in 1991 and 1992, were located on dry upland ridges and exposed to terrestrial predators. They were not visited during egg collections and both failed. Six other nests (one each in 1976, 1978, 1983, 1989, two nests in 1980) were located in sites without measurable water within 1 m of the nest edge. A nest built in 1989 by novice breeders was on relatively dry ground in Swamp Birch 6 m from a dry cattail stand. Tracks and trails showed that the pair had collected cattail from the nearby stand but had constructed the nest amongst the birch; the nest would have been less conspicuous if built in cattail. The pair successfully hatched a substitute egg (its own eggs were non-viable).

The foundation of nests in wet sites consisted of the rhizomes and rootstocks of bulrush and sedge with their adhering mud. Construction of this base was observed from the air on several occasions. Adults, working beside the nest site, pulled the desired material from the bottom of the nest pond and with a flick of the head tossed it sideways or over their back to the selected spot. The resultant small dark islet could be seen easily from the air. On this base, the cranes deposited a bulky mass of the (dead) previous year's growth of bulrush, sedge or cattail. Emergent vegetation was nipped off a few cm above the water surface. The removal of these plant stems often created a conspicuous circular "moat" around the nest. The buoyant leaves and stems of emergent plants were useful as nest material in aquatic situations.

Nest bottoms usually were dry, sometimes slightly damp and rarely (in some cattail nests) soggy. Bulrush was the sole or major building material in 235 (78.3%) of 300 nests examined in 1975-1991, with sedge (51 nests or 17%) and cattail (14 nests or 4.7%) making up the balance of nests. Nesting material consisted almost entirely of these three emergent plant groups. The basal portions of some nests contained small amounts of bryophytes such as *Scorpidium scorpioides* and *Drepanocladus revolvens*. Although several other plant species were collected from nest ponds, except for an occasional stem of Water-milfoil (*Myriophyllum exalbescens*) they did not appear as nest material.

Six of eight nests in cattail stands were composed of cattail and were located in relatively deep ponds (25-30 cm). Egg collections from these nests were often difficult because of the water depth and a treacherous, sometimes quaking, bottom.

In 1967-1991, I observed 10 floating nests, including the creek nest mentioned above. All were made of bulrush and occurred in high water years. Nest pond depths in these instances varied from 32 to 40 cm, well above the average for those years. Nests were located in stands of bulrush and it is likely that the rising water had lifted the buoyant nests from their bases. None was in danger of drifting away as all were surrounded by emergent vegetation.

During high-water years (Kuyt et al. 1992), 182 nests consisted chiefly or entirely of bulrush whereas 83 nests consisted of sedge, with a ratio of bulrush: sedge of 2.2:1. During low-water years when 73 nests were examined, 61 nests consisted chiefly or entirely of bulrush, for a bulrush: sedge ratio of 5.1:1. In high-water years, most sedge meadows became inundated and some were used as nest sites, where sedge was the dominant nest material. In low-water years, sedge meadows were not favoured as nesting areas, and most nests were found in bulrush. A G-test indicated that nest material was correlated with water depth of nest ponds ($G = 6.801$, $df = 1$; $p = 0.009$).

Nest Size and Re-use of Nests

Mean diameter and height above water of 273 nests measured between 1976 and 1989 was 117.4 cm (range 75-180 cm, S.D. 17.60) and 13.6 cm (range 5-35 cm, S.D. 4.48), respectively. Nest height increased when water depth of nest pond increased (Figure 1). After removal of overdue eggs from five

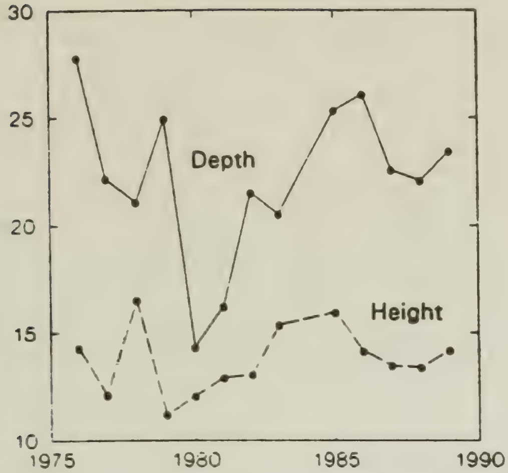

FIGURE 1. Relationship between mean water depth of nesting ponds and nest height above water, 1976-1989.

nests in 1976 and 1977, 15-33 days after the initial egg pick up, I again measured the nest heights. Nest heights were reduced, probably by movements of the adults during incubation which would tend to compact nests. Interpretation of results is difficult as it is unknown whether or not cranes habitually add nest material during incubation.

Nests gradually deteriorated due to movement of the adults on and near nests, weathering, and new plant growth. Although small, natural nest islets were sometimes used several times (new nest material was used each year), old nest structures were rarely occupied in successive years. In 1980, one nest was the same structure used in the previous year. This was the first time in 206 nests I examined in 1966-1980 that a pair had utilized the same nest in successive years. Clearly, Whooping Cranes prefer building a new nest each year.

Whooping Cranes display a strong attachment to the previous year's nest site. Successive nests were often located in the same area of the marsh (Kuyt and Goossen 1987; Kuyt 1993). In 1984-1989 a pair nested in the same bulrush stand in a 100 x 75 m pond, successfully fledging a chick annually. Nest marshes remained as potential nest sites for many years even though they were not always used. In 1990, I found a nest within 50 m of the site where Fuller found the first nest in 1955 (Allen 1956); I know that no nests were in the vicinity between 1966 and 1989.

Nest Parasitism

Pairs constructed new nests annually, shared incubation duties, were attentive at nest sites and are of imposing size. Under these conditions, nest parasitism (use of nest by birds other than the resident pair) is unlikely. Only one such record is known, that of a Sandhill Crane, *Grus canadensis*, laying an egg in a Whooping Crane nest. The Whooping Cranes successfully incubated their own two eggs and the sandhills' egg until the egg pick-up. All three eggs including the single Whooping Crane egg left in the nest eventually hatched (Kuyt 1989).

Nesting Chronology and Incubation Period

Most experienced breeding pairs arrived on the nesting area during late April. Depending on weather conditions, 5-10 days might lapse before nest construction began. Nest building was observed 29 April-11 May for these pairs, and about 2 days after nest construction began first eggs were laid. The earliest nestings occurred in 1976, 1977 and 1987 when clutches of two eggs were recorded on 28 April (Kuyt 1992). Most clutches were completed by early May, and by 12 May, 92% of eggs had been laid. In exceptional cases, nests were completed after eggs had been laid. In a few nests, full clutches were observed on bare mud nest bottoms, but by the time of egg collection nests were completed with plant material in place.

The incubation period was 29-30 days (Kuyt 1982), and eggs in the nest hatched asynchronously. Whooping Cranes frequently continued incubating addled eggs over a week beyond normal incubation. In 1987, a pair lost its single egg to an unknown predator, but the birds continued to sit on the empty nest for 11 days. The pair was given a substitute egg which it accepted and hatched, and a chick was fledged.

Clutch Size

In 1966-1991, 514 clutches were known to have been laid. Clutch size of 500 nests was determined; 454 (90.8%) contained 2 eggs, 43 (8.6%) had single eggs, and 3 nests (0.6%) had 3 eggs each. A comparison of the 1966-1991 data with the records for 1966-1980 (Kuyt 1981) showed that the proportion of 2-egg clutches remained the same after 1980 with a slight increase in single egg clutches. This increase may be due, in part, to an increase in the proportion of young breeders with associated smaller clutches (Pettingill 1971). Clutch sizes during low water periods (1980-1981; 1990-1991) were compared with those of high water periods (1966-1979; 1982-1989, Kuyt et al. 1992). Clutch sizes were significantly larger in high water years than in low water years ($t = 2.29$, $df = 137$; $p < 0.05$). Results were still significant when 3-egg clutches were omitted ($P = 0.037$).

Description of Egg

Size

Viable Whooping Crane eggs had a mean weight of 193.2 g each (Table 1), and at approximately 24 d incubation the egg constituted about 3.3% of the

TABLE 1. Measurements of Whooping Crane eggs by categories, 1967–1991.

Egg category	Length (mm) $\bar{x}$ ± S.D. (N) min.-max.	Width (mm) $\bar{x}$ ± S.D. (N) min.-max.	Weight (g) $\bar{x}$ ± S.D. (N) min.-max.
Viable eggs	100.6 ± 4.18 (234) 88-112	62.9 ± 2.01 (234) 57-73	193.2 ± 14.27 (201) 141.3-242.7
Eggs without detectable embryos (excluding infertile eggs)	101.4 ± 4.44 (51) 91-112	63.4 ± 1.72 (51) 59-67	193.6 ± 17.66 (44) 133.5-232.0
Eggs with unknown contents (including eggs destroyed by predators)	99.4 ± 5.58 (15) 92-112	62.7 ± 2.40 (15) 58-66	187.2 ± 16.83 (11) 157-210.4
Infertile eggs	102.3 ± 3.08 (19) 95-107	62.9 ± 1.82 (19) 60-66	196.6 ± 13.97 (19) 172-223.0

average adult female crane's body weight (i.e., 6.4 kg, U.S. Fish and Wildlife Service 1994). This agrees with observations that larger birds lay proportionally smaller eggs than small birds (Pettingill 1971). Avian eggs begin to lose weight by evaporation immediately after having been laid (Romanoff and Romanoff 1949). Developing live eggs lose water faster than addled eggs because of the combination of water loss from evaporation and embryo metabolism (Drent 1970). Loss of weight of five eggs without detectable embryos (weight loss by evaporation only) over periods from 14 June to 9 July averaged 0.3 g/day. Weights of freshly laid eggs were not available as examination of nests and eggs occurred mainly during late incubation.

Egg measurements (length, width, weight) showed that width was the most constant of the measurements (Table 1). Romanoff and Romanoff (1949) related this to the fact that the egg originates in a tube whose cross-sectional area has a limited extensibility.

Eggs with no detectable embryos did not differ in size from eggs with unknown contents but 19 infertile eggs were longer than normal, viable eggs (Mann-Whitney test: $U = 1558.0$, $N_1 = 234$, $N_2 = 19$; $P < 0.05$). Three combinations of eggs from the same clutch (both eggs alive, both with no detectable embryo, and one egg of each category) were tested and eggs did not differ in terms of length, width and weight, except when both eggs were viable, in which case the width differed significantly (Wilcoxon signed rank test: $T = 18$, $N = 29$; $P < 0.05$).

Eggs of Novice Layers

Fourteen eggs of known first-time breeders (13 live eggs and one egg with contents unknown) were compared with 221 viable eggs of experienced breeders. Mann-Whitney tests showed no significant differences in length of these two groups but novice layers' eggs were significantly narrower and weighed less ($P < 0.05$) than other eggs. The average size of the eggs laid by an individual domestic hen is smallest during its first year and increases thereafter until it reaches a maximum (Romanoff and Romanoff 1949).

Eggs of females of unknown age paired with known-age males breeding for the first time were compared with these pairs' second-year clutches. First-year eggs were narrower than those of the following year (Wilcoxon signed rank test: $T = 19.0$, $N = 7$; $P < 0.05$), but lengths were similar. Although 4 of 5 eggs were heavier in the second year of breeding, the differences were not significant.

Egg Shell Weight

Mean weight of 23 egg shells from failed (overdue) eggs was 24.3 g. Five shells were from infertile eggs and their mean weight constituted 11.2% of the mean weight of infertile eggs. Similarly, mean weight of 13 shells of eggs without detectable embryos was 12.8% of mean weight of these eggs. Romanoff and Romanoff (1949) reported an average shell weight of 11.9% of eggs from 10 different species of precocial birds.

Egg Shape

The shape of the avian egg varies considerably, from almost spherical to elliptical, subelliptical, oval and conical (Romanoff and Romanoff 1949; Harrison 1978). The Whooping Crane egg is described as subelliptical (Harrison 1978) or elliptical ovate (Bent 1926), and resembles the shape referred to as biconical or ellipsoidal (Romanoff and Romanoff 1949). The egg is rounded at both ends but a little more tapering on the cloacal (sharp) end. The widest part is closer to the blunt pole than to the sharp end. The egg generally has a smooth surface with occasional small granular deposits near the infundibular (blunt) end.

The shape index for viable Whooping Crane eggs, derived from the ratio (egg width:egg length) x 100, equals 63 (n = 234), compared with an egg shape index of 90 for the almost spherical egg of the Hooded Merganser, *Lophodytes cucullatus*, and an index of 50 for the conical egg of a guillemot (probably Common Murre, *Uria aalge*; Romanoff and Romanoff 1949).

Egg Colour

Whooping Crane egg colour varies considerably and is difficult to describe. Typical eggs had little or no gloss, and the ground colour, determined by shell pigment, varied from greenish-olive to buffy-olive. The cuticular pigment consisted of unevenly distributed blotches, spots and small specks of various shades of brown or even light purple, particularly near the blunt pole. It is this part of the egg that first leaves the cloaca and thereby receives most of the pigment. Some pairs produced light brown eggs whereas one pair, habitually nesting in a cattail marsh, always produced dark olive eggs. Sometimes the difference in colour between the eggs in the same clutch was so pronounced that it could be detected from a low-flying aircraft.

Acknowledgments

This paper is dedicated to the memory of pilot Joseph William "Billy" Bourque of Fort Smith, N.W.T., who died in an aircraft crash on 22 May 1993. Billy flew his first Whooping Crane survey with me on 3 May 1974 and he provided almost 20 years of dependable and dedicated service.

In the early years of the project, R. C. Erickson and G. Smart (USFWS) were major cooperators during the removal and transport of collected eggs. They, and others of the Patuxent Research Center, Maryland, provided information on egg fertility. CWS employees B. E. Johnson, J. P. Goossen, B. W. Johns and H. J. Armbruster assisted during aerial surveys and egg collections, and in many other capacities. R. C. Drewien and E. G. Bizeau, Idaho Cooperative Wildlife Research Unit, Moscow, Idaho, assisted in the field work and remained sources of inspiration throughout the project. S. J. Barry (CWS) carried out the statistical analyses. U. Banasch (CWS) provided electric egg incubators, and portable incubators were provided each year by the USFWS, Patuxent Research Center.

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Introduced Rats, *Rattus* spp., on the Queen Charlotte Islands: Implications for Seabird Conservation

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Bertram, Douglas F., and David W. Nagorsen. 1995. Introduced rats, *Rattus* spp., on the Queen Charlotte Islands: Implications for seabird conservation. Canadian Field-Naturalist 109(1): 6–10.

Since the 1950s, some large seabird colonies on the Queen Charlotte Islands archipelago in British Columbia have undergone major declines. Predation from introduced rats has contributed to declines in burrow-nesting seabirds, especially the Ancient Murrelet (*Synthliboramphus antiquus*). A review of historical museum records, published observations, and recent field surveys revealed that rats have been recorded on 18 islands; seven of these islands presently support colonies of burrowing seabirds. Our review suggests that the Norway Rat (*Rattus norvegicus*) has recently displaced the Black Rat (*Rattus rattus*) on Langara Island and possibly Kunghit Island. Implications for seabird conservation and rat control programs are discussed.

Key Words: Norway Rat, *Rattus norvegicus*, Black Rat, *Rattus rattus*, seabird colonies, predation, control programs.

The Queen Charlotte Islands (or Haida Gwaii) is an isolated archipelago of about 150 islands situated off the west coast of British Columbia. The archipelago supports large numbers of breeding seabirds. In the past few decades, however, some seabird colonies have exhibited disturbing declines. Langara Island, for example (Figure 1), once supported one of the largest seabird colonies in British Columbia (Drent and Guiguet 1961; Gaston 1992). Six burrow-nesting seabirds nested on the island: Ancient Murrelet (*Synthliboramphus antiquus*), Cassin's Auklet (*Ptychoramphus aleuticus*), Fork-tailed Storm-Petrel (*Oceanodroma furcata*), Leach's Storm-Petrel (*Oceanodroma leucorhoa*), Rhinoceros Auklet (*Cerorhinca monocerata*), and Tufted Puffin (*Fratercula cirrhata*). The most abundant was the Ancient Murrelet and before the 1950s, a breeding population estimated at 200 000 pairs nested around the entire perimeter of the island (Beebe 1960; Gaston 1992).

Since the 1950s, seabird populations declined on Langara Island. By 1988, five burrow-nesting

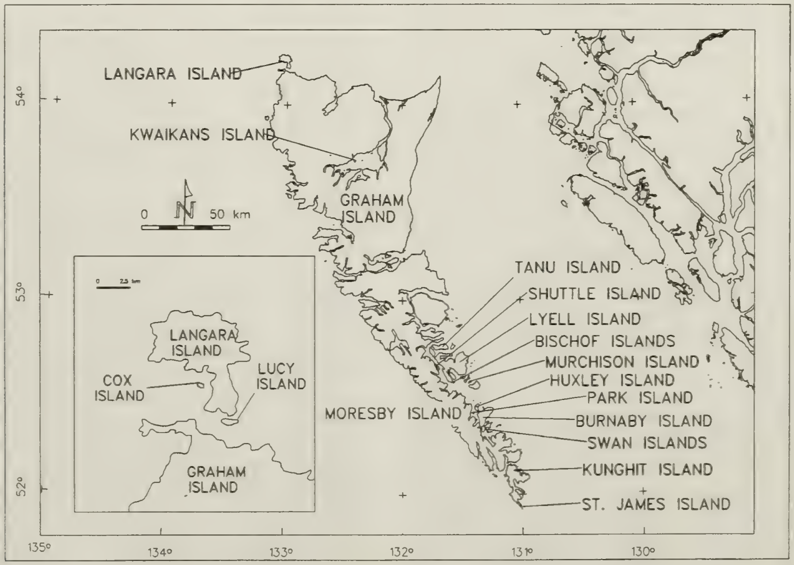

FIGURE 1. Islands in the Queen Charlotte Islands (Haida Gwaii) archipelago of British Columbia with introduced rats.

TABLE 1. Summary of known Black Rat (*Rattus rattus*) and Norway Rat (*Rattus norvegicus*) records from the Queen Charlotte Islands. BCPM = Royal British Columbia Museum; NMC = Canadian Museum of Nature; ROM = Royal Ontario Museum; UBC = Cowan Vertebrate Museum, University of British Columbia.

Island	Species	Year	Source
Burnaby	*R. rattus*	1946	UBC
Bischof	*Rattus* sp?	1992	Burles (unpublished data)
Cox	*Rattus* sp?	1993	G. Kaiser (unpublished data)
Graham	*R. rattus*	1919	NMC
	R. rattus	1930	ROM
	R. rattus	1935	ROM
	R. rattus	1946	UBC
	R. norvegicus	1985	BCPM
Huxley	*Rattus* sp?	1992	Burles (unpublished data)
Kingfisher[1]	*R. rattus*	1960	UBC
Kunghit	*R. rattus*	1946	UBC
	Rattus sp?	1991	Masselink and vanden Brink (unpublished data)
	R. norvegicus	1993	BCPM; Harfenist (1994)
Kwaikans	*R. rattus*	1960	UBC
Langara	*R. rattus*	1946	UBC
	R. rattus	1947	UBC
	R. rattus	1966	Campbell (1968)
	R. norvegicus	1988	BCPM; Bertram (1995)
	R. norvegicus	1993	BCPM; Harfenist (1994)
	R. norvegicus	1994	BCPM; Howald (unpublished data)
Lucy	*R. norvegicus*	1993	UBC
	R. norvegicus	1994	Howald (unpublished data)
Lyell	*R. rattus*	1960	UBC
	R. rattus	1982	UBC; Gaston (1992)
	R. rattus	1993	Gaston (1993)
Moresby	*R. rattus*	1946	UBC
	R. rattus	1961	NMC
	R. rattus	1974	BCPM
Murchison	*R. rattus*	1960	UBC
	Rattus sp?	1984	Rodway et al. (1988)
	R. rattus	1992	Gaston (unpublished data)
Park	*Rattus rattus*?	1984	Rodway et al. (1988)
Shuttle	*Rattus* sp?	1991	Masselink and vanden Brink (unpublished data)
St. James	*R. norvegicus*	1981	BCPM
	R. norvegicus?	1993	G. Kaiser (unpublished data)
Swan	*Rattus* sp?	1991	Burles (unpublished data)
Tanu	*Rattus* sp?	1992	Burles (unpublished data)

[1]may be an unnamed islet in Kingfisher Cove near Burnaby Island, or one of the Swan Islands.

species were gone and the Ancient Murrelet colony consisted of only 24 000 pairs confined to a small area (48 ha) on the northwestern side of the island (Bertram 1989, 1995). Populations of Ancient Murrelets on nearby Cox and Lucy islands (Figure 1) were abandoned by 1970 (Gaston 1992). A survey of Langara Island in 1993 by the Canadian Wildlife Service revealed that since 1988 the extent of the colony decreased by 50% and the breeding population declined by 40% (Harfenist 1994). Similar declines in Ancient Murrelets have occurred on Lyell Island (Lemon 1993) and possibly Kunghit (Harfenist 1994) and Murchison islands (Gaston 1992, 1994). A small population of 500 pairs of Ancient Murrelets that once nested on the Bischof Islands disappeared by 1985 (Rodway et al. 1988).

Introduced Black Rats (*Rattus rattus*) and Norway Rats (*Rattus norvegicus*) have been implicated as a contributor to the Ancient Murrelet declines (Bertram 1989, 1995; Gaston 1992, 1994) and the

TABLE 2. Size and the degree of isolation of eight burrow-nesting seabird islands in the Queen Charlotte Islands with introduced rats. Distance to mainland= minimum distance to Graham or Moresby islands

Island	Area (ha)	Distance to Mainland (km)	Distance to Nearest Rat Island (km)	Nearest Rat Island
Bischof	86	3.18	0.51	Lyell
Cox	8	2.12	0.15	Langara
Kunghit	12987	0.86	0.25	St. James
Langara	3253	1.11	0.15	Cox
Lucy	42	0.95	0.20	Langara
Lyell	17452	1.51	1.47	Shuttle
Murchison	431	7.31	1.61	Lyell
St. James	22	22.69	0.25	Kunghit

Canadian Wildlife Service has been developing a strategy to eradicate rats from Langara. Nonetheless, the distribution of rats on the various islands of the Queen Charlottes has not been well documented. Moreover, recent observations suggest that *R. norvegicus* may have displaced *R. rattus* on several islands. Herein, we review historical and recent rat records from the Queen Charlotte Islands and discuss the implications of rat distributions for seabird conservation.

Methods

Historical records were derived from published literature and museum records. Museum records of rats from the Queen Charlotte Islands were extracted from a database containing all mammal specimens from British Columbia housed in 25 North American museums; rat specimens were located in four museums. All museum specimens were examined to verify identification.

Recent records were based on sightings, droppings, and skulls found on islands during seabird inventories conducted by the Canadian Wildlife Service. In addition, Canadian Wildlife Service teams deployed live and Victor rat traps on Langara Island in 1988 (390 trap nights) and 1993 (65 trap nights), Lucy Island in 1993 (12 trap nights), and Kunghit Island in 1993 (9 trap nights) (Bertram 1989; Harfenist 1994; Kaiser, personal communication); and Gregg Howald (personal communication) trapped Lucy Island (unknown trap nights) and Langara Island (648 trap nights) in 1994 with Victor rat traps. Voucher specimens of rats collected (1988-1994) on Langara Island and Kunghit Island were deposited in the collections of the Cowan Vertebrate Museum, University of British Columbia and the Royal British Columbia Museum.

Island areas were obtained from Hartman (1993). Two measures of isolation were used: distance to mainland (i.e., the minimum distance to Graham or Moresby islands) and the minimum distance to nearest known rat population. We measured distances from 1:50 000 topographic maps.

Results and Discussion

The history and origin of rats on the Queen Charlotte Islands is obscure. It is generally assumed that Graham and Moresby, the two largest islands in the archipelago, were colonized by rats that escaped from ships of early European explorers and fur traders (Foster 1989). Nonetheless, Osgood (1901), in the first survey of the mammalian fauna of the Queen Charlotte Islands, made no mention of *R. rattus* and noted that *R. norvegicus* "had not yet obtained a foothold on the islands". The oldest museum specimen that we found was a specimen of *R. rattus* taken on Graham Island in 1919. Rats have now been recorded from 18 islands in the archipelago (Table 1; Figure 1). Seven of these islands presently support colonies of burrow-nesting seabirds: Bischof (Leach's Storm-Petrels, Fork-tailed Storm-Petrels); Cox (Tufted Puffins); Kunghit (Ancient Murrelets, Cassin's Auklet, Rhinoceros Auklet, Tufted Puffins); Langara (Ancient Murrelets); Lyell (Ancient Murrelets); Murchison (Ancient Murrelets, Cassin's Auklet); and St. James (Tufted Puffins) (Rodway et al. 1988; Gaston 1994).

The first verified record of *R. norvegicus* in the Queen Charlotte Islands was in 1981 (Table 1). All previous verifiable records were *R. rattus*. Our data show that *R. norvegicus* has appeared on five of these seabird islands within the past two decades and may be replacing *R. rattus*. *R. rattus* was first taken on Langara Island in 1946 (Table 1). This species was last reported on Langara Island in 1966 (Campbell 1968), although no voucher specimens were taken to confirm the identification. Rats captured in 1988, 1993, and 1994 on Langara were all *R. norvegicus*. As well, *R. norvegicus* were captured in 1993 and 1994 on Lucy Island, and droppings

(probably *R. norvegicus*) were observed by G. Kaiser on Cox Island in 1993. It is not known if both rat species still exist on Langara Island but competitive displacement of the smaller *R. rattus* by *R. norvegicus* especially on islands has been well documented (Barnett and Spencer 1951; Ecke 1954; Taylor 1975). A similar displacement may have occurred on Kunghit Island. With no records available before 1981, the historical situation on St. James Island is unknown.

The occurrence of *R. norvegicus* on Langara, Kunghit, and St. James islands has significant implications for seabird conservation efforts. Because *R. norvegicus* is larger than *R. rattus*, it may represent a greater threat to seabirds. Moors and Atkinson (1984) concluded that the size and behaviour of the predator and prey species contributed to the severity of predation by introduced rats and Imber (1975) noted that seabirds are most endangered if invaded by a species of rat with a body weight equal to or greater than that of the seabird species. Weights for three adult *R. norvegicus* captured on Langara Island ranged from 299 to 434 g; according to Sealy (1976) mean weight for the Ancient Murrelet is about 206 g.

According to Taylor (1984, 1993*), *R. rattus* and *R. norvegicus* are weak swimmers and they usually cannot swim across straits beyond 250 to 300 m in temperate seas. Sea surface temperatures around the Queen Charlotte Islands are cool, ranging from a summer maximum of 10 to 13°C to minimums of 4 to 8°C in winter (Thomson 1989). Passive "rafting" to the various islands also seems unlikely. Therefore, rats probably reached the seabird islands of the Queen Charlotte Islands by human transport. Overwater dispersal from Graham or Moresby islands is improbable (Table 2). Light station construction in the early 1900s, the military presence during World War II, barge traffic for forestry and mining operations, and intense salmon fishing in the 1950s and 1960s are all activities through which introductions may have occurred. The exact dates and source of the recent *R. norvegicus* introductions are unknown. Langara and St. James islands have light stations and *R. norvegicus* may have been transported in vessels supplying these stations.

With areas ranging from 8 to 86 ha, extinction rates would be expected to be high on Bischof, Cox, Lucy, and St. James islands. Bischof is beyond the dispersal distance for *R. rattus* on Lyell, the nearest potential source area. The rat populations on Lucy and Cox are probably dependent on recurrent immigration from nearby Langara. The situation on St. James is not clear but Kunghit could be a source area for re-invasion if the St. James population suffered local extinction. Kunghit Island is only 250 m from St. James Island with an intervening stepping-stone island situated at 100 m distance. The other seabird islands with introduced rats are large enough to maintain viable rat populations (Table 2). However, because of their isolation, ongoing colonization of these islands by rats from the mainland (i.e., Graham or Moresby) is unlikely. This is contrast to the situation with the introduced Raccoon (*Procyon lotor*), which is capable of reaching most seabird islands by swimming (Hartman 1993). Eradicating introduced rats from islands such as Bischof, Cox, Langara, and Lucy should be feasible. However, it may not be possible to eliminate rats from the large seabird islands such as Lyell and Kunghit (G. Kaiser, personal communication).

The Canadian Wildlife Service is pursuing plans to eradicate *R. norvegicus* from Langara Island using techniques that were successful in New Zealand (Taylor 1993*). However, the recent introductions of *R. norvegicus* to the Queen Charlotte Islands underscore the need for programs that will prevent new introductions and quickly eliminate any new rat populations. Additional monitoring and surveys are also required. The status of rats should be assessed for seabird islands such as Bischof and St. James. A rat inventory is also warranted for Burnaby Island, where there is a historical museum record of *R. rattus*. Although there are no burrow-nesting seabirds on Burnaby, the island could be a potential source area for nearby seabird islands such as Alder Island.

Acknowledgments

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*Denotes unpublished document, see Documents Cited which proceeds Literature Cited.

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Early Holocene Black Bears, *Ursus americanus*, From Vancouver Island

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Skeletal remains of three bears found in a cave on Vancouver Island were radiocarbon dated as early Holocene (9830±140 BP). Pollen analysis of sediments adhering to bones indicated that the bears lived in an environment of mixed coniferous forest with a warmer drier climate than today. Cranial and dental measurements from the cave specimens were compared with historical museum specimens of *Ursus arctos* and *Ursus americanus vancouveri*. Although the palaeontological specimens are larger than modern *U. a. vancouveri* specimens, they were identified as *U. americanus* from dental size. The presence of large *U. americanus* on Vancouver Island in the early Holocene is consistent with the relictual hypothesis that attributes insular gigantism to colonization of the Pacific Northwest islands by large bears in the early post-glacial.

Key Words: Black Bear, *Ursus americanus*, Grizzly Bear, *Ursus arctos*, fossils, insular gigantism, pollen analysis, early Holocene, Vancouver Island, British Columbia.

Black Bears (*Ursus americanus*) inhabiting the large islands of the Pacific Northwest (Vancouver Island, Queen Charlotte Islands, and Alexander Archipelago) are strongly differentiated from mainland populations by their broad massive skulls and robust dentition (Hall 1928; Anderson 1945; Cowan and Guiguet 1965). Two hypotheses have been invoked to explain these large insular morphs. Foster (1965) and Gordon (1986) interpreted them as relictual populations derived from large forms of *U. americanus* that inhabited North America in the Pleistocene and early Holocene. Alternatively, they may be derived recently from a small mainland ancestor and their large size has evolved in response to selection pressures that favour insular gigantism (Case 1978; Lomolino 1985).

Any interpretation of the historical biogeography and body size evolution for insular bears from the Pacific Northwest has been hindered by the lack of fossil material. Until our study, no palaeontological specimens were known from coastal British Columbia, and palaeontological material from southeastern Alaska is limited to several early postglacial specimens of *U. americanus* and Grizzly Bear (*Ursus arctos*) recently discovered on Prince of Wales Island (Heaton and Grady 1992, 1993).

In 1983, cavers discovered the skeletal remains of three bears in Windy Link Pot Cave, Vancouver Island. Radiometric analysis of bones and pollen analysis of sediments associated with the cave specimens were used to determine the palaeobiological context of the cave bones. Because the bear skulls are well preserved with their dentition largely intact, they provided an opportunity for a comprehensive morphometric analysis.

There were two objectives to our study. One was to verify the identification of the cave specimens as *U. americanus*. Although *U. americanus* is the only bear species inhabiting the coastal islands of British Columbia and southern islands of the Alexander Archipelago today (Cowan and Guiguet 1965; Klein 1965), the co-occurrence of late Pleistocene fossils of *U. americanus* and *U. arctos* on Prince of Wales Island in the Alexander Archipelago (Heaton and Grady 1992, 1993) is evidence that the two species could have coexisted on British Columbian islands in the early postglacial. Our second objective was to compare the size of the cave specimens with modern Black Bear skulls from Vancouver Island to test the relictual hypothesis of Gordon (1986).

Study Area

Windy Link Pot Cave is situated at about 900 m asl (above sea level) on White Ridge near Gold River, in an extensive karst (Figure 1). The cave lies in the Coastal Western Hemlock biogeoclimatic zone near the lower boundary of the Mountain Hemlock zone (Anonymous 1985*). This zone is characterized by a cool mesothermal climate with heavy precipitation; Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is the predominant forest tree species (Meidinger and Pojar 1991*).

The cave system is immense, extending for nearly 10 km underground with several steep drops in the cave floor. The cave entrance drops 78 m vertically to the cave floor. All bear bones were collected from

*see Documents section preceeding Literature Cited

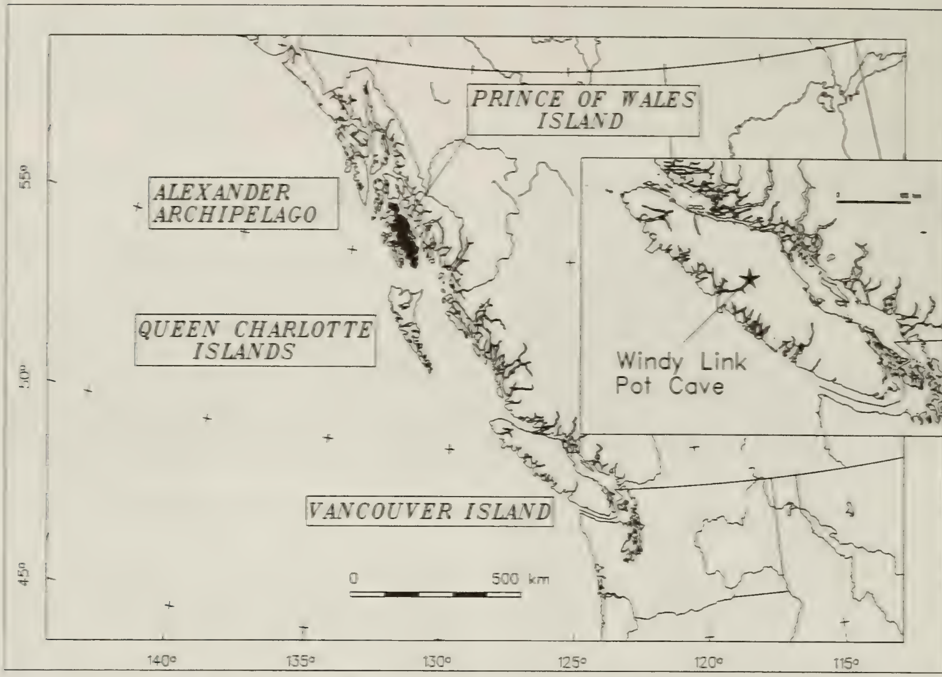

FIGURE 1. Islands in the Pacific Northwest mentioned in text and location of the study area on Vancouver Island (inset).

the same location at the bottom of the 78 m entrance pitch. They were covered with fine, water-deposited silt. Bones of three Black-tailed Deer (*Odocoileus hemionus*) were found in three nearby locations. The deer and bear bones showed no evidence of human butchering or carnivore tooth marks and the animals presumably fell into the cave.

A sample of silty sediment that adhered to the bear bones was processed for pollen analysis following conventional techniques (Faegri and Iversen 1975).

Materials and Methods

Bear Specimens

Bear specimens from the cave consist of: two skulls with associated mandibles (BCPM 17198, 17199), a single dentary (BCPM 19030), three right ribs, two vertebrae (lumbar and thoracic), two tibias (right and left), two femurs (right and left), a partial right humerus, right ulna, and a metatarsal. The postcranial elements are all from an immature individual (epiphyses not ossified) and may be associated with the immature skull (BCPM 17199).

BCPM 17198 is an incomplete skull (Figure 2) and left dentary (Figure 3). Maxillary teeth consist of: left fourth premolar (P^4), left first molar (M^1), and left and right second molars (M^2). Only the canine tooth is present in the dentary. This was an old individual with a completely fused basioccipital-basisphenoid suture and worn cusps on M^1 and M^2. The bell-shaped temporal ridges (Marks and Erickson 1966) suggest a female.

BCPM 17199 consisted of a skull fragment and both dentaries (Figure 3). Maxillary teeth present are both pairs of molars (M^1, M^2); the left second premolar (p_2) is in the right dentary and the canine is in the left dentary. The specimen is immature (open cranial sutures and no wear on the teeth).

BCPM 19030 consists of a complete left dentary (Figure 3) with only the canine tooth.

Radiocarbon Dating

A composite bone sample weighing 231.8 g was submitted to Beta Analytic Incorporated, Miami, Florida for a conventional radiocarbon (^{14}C) assay. The sample included both tibias, the three ribs, and two vertebrae.

Measurements

We used five dental measurements (nearest 0.1 mm) defined by Manning (1971) and Gordon (1977, 1986): length of maxillary toothrow (LP^4-M^2), length from anterior alveoli of P^4 to posterior alveoli of M^2; length of first upper molar (LM^1), maximum crown length of M^1; length of second upper molar (LM^2), maximum crown length of M^2; width of second upper molar (WM^2), maximum crown width across M^2; length of mandibular toothrow (Lp_4-m_3), length from anterior alveoli of fourth mandibular

FIGURE 2. Ventral view of BCPM 17198 skull.

premolar (p_4) to posterior alveoli of third mandibular molar (m_3).

Six cranial measurements based on Manning (1971) were taken to the nearest mm: basilar length (BAL), length from anterior extremity of premaxilla (excluding teeth) to anterior extension of foramen magnum; palatal length (PAL), length from anterior extremity of premaxilla to the posterior border of palate; interorbital breadth (IB), minimum width between orbits measured across the frontals; supraorbital breadth (SB), maximum breadth across supraorbital processes; least cranial breadth (LCB), minimum width of cranium posterior to the supraorbital processes; mastoid breadth (MB), maximum width across mastoid processes.

Analyses

Comparative reference samples of *U. americanus* and *U. arctos* consisted of historical museum specimens (Appendix I). For *U. americanus*, we used 32

FIGURE 3. Lateral view of four dentary bones: BCPM 19030 (top left), BCPM 17198 (bottom left), BCPM 17199 (top and bottom right).

TABLE 1. Frequency of pollen types from a sample of silty clay adhering to bear bones from Windy Link Pot cave, Vancouver Island (n=55).

Pollen type	Percent (%)
Abies	29.1
Tsuga heterophylla	29.1
Pseudotsuga	14.5
Alnus	7.3
Picea	7.3
Pinus contorta	7.3
Cupressacae	1.8
Selaginella	1.8
Tsuga mertensiana	1.8

male and 21 female skulls with fully erupted permanent dentition from Vancouver Island (i.e., *U. americanus vancouveri*). Mature skulls with the basioccipital-basisphenoid suture fused (class VIII of Rausch 1961) were used in the analysis of cranial measurements. The *U. arctos* sample comprised 17 immature skulls (basioccipital-basisphenoid suture open, fully erupted permanent dentition) from the Kootenay region of southeastern British Columbia. Because we wanted a sample of *U. arctos* that potentially overlapped with *U. americanus* in cranial and dental size, we selected a population characterized by small cranial size (see Rausch 1963) and restricted our reference group to young animals. Identification was based on the five dental measurements. Non-metric traits such as the presence or absence of accessory cusps on p_4 and m_1 (Verlaine-Wright et al. 1988*; Graham 1991) could not be used because these teeth were missing from our specimens.

To assess size differences among the cave specimens and modern Black Bears, we compared individual measurements of cave specimens with means of reference samples for *U. americanus vancouveri* using a one-tailed Student's t-test. We also used a principal components analysis to develop a multivariate measure of dental size. With this multivariate technique, components are derived from linear combinations of the original variables; the components take into account the variances and covariances of the original variables. Our analysis was based on a subset of *U. a. vancouveri* (28 male, 19 female) with no missing measurements and the cave specimens with teeth (BCPM 17198, 17199). Components were extracted from a variance-covariance matrix derived from the five dental measurements ($\log_{10}$ transformed). Scores of individuals on the first component (a size vector) were plotted as histograms. All analyses were done with SYSTAT programs (Wilkinson 1990).

Results

Geological Age of Cave Specimens

Radiocarbon analysis of the postcranial elements revealed a conventional date of 9760 ± 140 BP and a corrected date of 9830 ± 140 BP (sample Beta-10714).

Pollen Analysis

Pollen preservation was poor with many corroded grains and pollen concentration was low. Except for a single *Selaginella* spore, the assemblage was composed of arboreal types (Table 1). Fir, *Abies* sp. (presumably from Pacific Silver Fir, *Abies amabilis* (Dougl.) Forbes) and Western Hemlock, *Tsuga heterophylla* (Raf.) Sarg.) pollen predominated, but there were significant amounts of Douglas-fir *Pseudotsuga menziesii* (Mirbel) Franco) and even some pine *Pinus* and spruce *Picea*. A large amount of charcoal was found in the sediment indicating past fires.

Identification

Ursus a. vancouveri demonstrates marked sexual dimorphism in size with females smaller in cranial and dental size (Tables 2 and 3). Adult male and female *U. a. vancouveri* overlap substantially in cranial size with the immature *U. arctos* (Table 2); however, extremes of the five dental measurements (Table 3) show no overlap among the two taxa. Thus, the two species can be unequivocally identified by dental size.

Based on molar size and toothrow length, we identified BCPM 17198, 17199, and 19030 as *U. americanus*. With the exception of LM[1] for BCPM 17198 which corresponds to the extreme minimum value for *U. arctos*, their measurements are smaller

TABLE 2. Cranial measurements (taken to nearest mm) for immature *Ursus arctos*, adult *U. americanus vancouveri*, and the early Holocene bear skull from Vancouver Island.

	U. arctos			*U. americanus* ♂			*U. americanus* ♀			17198♀
	X ± SD	Range	n	X ± SD	Range	n	X ± SD	Range	n	
BAL	266.0 ± 28.4	219-318	14	261.5 ± 8.5	247-281	17	228.0 ± 10.7	217-247	9	252
LPAL	150.6 ± 15.1	125-182	16	145.8 ± 3.7	140-154	17	128.8 ± 5.8	122-139	9	137
IB	64.7 ± 7.6	51-76	17	71.4 ± 4.4	63-78	20	62.3 ± 3.0	57-67	9	72
SB	92.6 ± 11.4	73-111	17	103.1 ± 6.8	87-118	20	89.7 ± 5.2	81-99	9	97
LCB	71.1 ± 2.71	67-76	17	67.9 ± 2.3	64-74	19	65.4 ± 2.4	63-69	9	70
MB	126.1 ± 18.3	95-164	17	138.7 ± 4.0	131-145	18	119.1 ± 9.6	107-134	8	125

TABLE 3. Dental measurements (taken to nearest 0.1 mm) for immature *Ursus arctos*, adult *U. americanus vancouveri*, and three early Holocene bears from Vancouver Island.

	U. arctos			*U. americanus* ♂			*U. americanus* ♀			17198♀	17199[a]	19030[b]
	X ± SD	Range	n	X ± SD	Range	n	X ± SD	Range	n			
LP^4-M^2	72.3 ± 3.9	66.9-78.9	17	56.1 ± 1.32	53.4-58.2	32	50.9 ± 2.20	47.5-57.7	21	66.5	56.3	—
LM^1	22.3 ± 0.87	21.0-24.2	16	18.3 ± 0.45	17.4-19.1	32	16.9 ± 0.50	16.1-18.0	21	21.0	19.4	—
LM^2	35.4 ± 1.79	31.6-38.8	16	27.4 ± 1.07	25.4-28.9	32	24.9 ± 1.13	23.1-27.3	20	28.3	28.3	—
WM^2	18.1 ± 0.67	16.9-19.1	17	14.7 ± 0.36	13.9-15.3	32	13.6 ± 0.43	12.8-14.4	20	15.5	15.1	—
Lp_4-m_3	80.2 ± 3.31	73.6-87.2	17	64.7 ± 1.95	60.7-68.7	29	57.5 ± 3.18	49.7-64.1	19	66.2	64.0	67.4

[a] immature, sex unknown
[b] adult, sex unknown

than the minimum measurements for immature Grizzly Bears (Table 3).

Relative Size of Cave Specimens

Cranial size could only be measured for BCPM 17198. BAL, IB, and LCB were larger than the maximum values of modern female *U. a. vancouveri* specimens (Table 2). LCB was larger than the mean female value ($P < 0.05$); LPAL and SB did not differ from means of modern females ($P > 0.10$).

The cave specimens generally have large teeth relative to modern *U. a. vancouveri* specimens (Table 3). All measurements of BCPM 17198 are beyond the maximum values of female *U. a. vancouveri*, and three measurements (LP^4-M^2, LM^1, and WM^2) are greater than extremes for males. LM^2 and Lp_4-m_3, however, were not larger than means for modern males ($P > 0.25$). LM^1 of BCPM 17199 is larger than the extreme value of male *U. a. vancouveri*; other dental measurements for this specimen do not differ from means for modern males ($P > 0.10$) but are larger than means for modern females ($P < 0.05$). Lp_4-m_3, the only measurement available for BCPM 19030, is larger than the mean for females ($P < 0.01$) but does not differ from the mean for males ($P > 0.05$).

The five dental variables have high positive loadings on principal component 1. This vector, a multivariate measure of "size", explains 84.3% of the variation in the dental variables. A histogram (Figure 4) of individual scores for component 1 demonstrate the tendency for large size in the two cave specimens with teeth. The dental size of BCPM 17199 is equivalent to that of a large modern male and BCPM 17198 is larger than any of the modern males. The size of BCPM 17198 is striking, especially if this specimen is a female.

Discussion

The composite ^{14}C date of about 9800 BP, indicates that the cave specimens are of earliest Holocene age. According to Claque (1981), glacial retreat began at least by 13000 BP on Vancouver Island, and by 10000 BP deglaciation was essentially complete. To date, all palaeontogical bear specimens recovered from Pacific Northwest islands (this study; Heaton and Grady 1992, 1993) are Holocene age. Thus, they provide no insight into the Pleistocene refugium hypothesis advocated by Foster (1965).

The pollen data demonstrate that the early Holocene environment around the cave consisted of mixed coniferous forest. *Abies* and *Pseudotsuga* (typically underrepresented in the pollen rain) were major elements of the forest with *Tsuga heterophylla* slightly less abundant. The percentages for *Picea*, presumably Sitka Spruce (*Picea sitchensis* (Bong.) Carr.) another relatively poorly represented species in the pollen rain, suggest that this tree also grew nearby. The pollen assemblage strongly indicates a

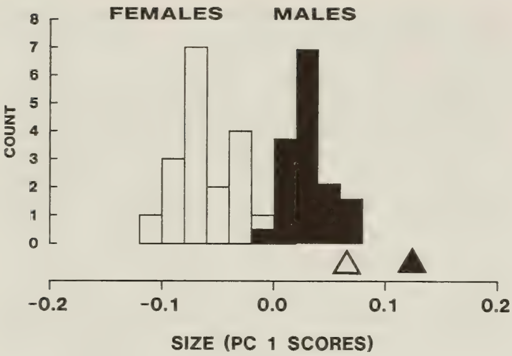

FIGURE 4. Histogram showing scores for modern *Ursus americanus vancouveri* and the two early Holocene specimens on the first principal component. The component is derived from the five dental measurements and describes a pattern of increasing dental 'size'. Open triangle = BCPM 17199 (adult female), closed triangle = BCPM 17198 (immature, sex unknown).

climate much warmer and drier than today, and a forest with different characteristics. *Pseudotsuga* and *Picea sitchensis*, for example, are not predominant in the study area today. The abundant charcoal in the sample, assuming that it came from a forest fire source, is further evidence for warm and dry conditions with high fire frequencies (Mathewes 1985). Although fires are almost unknown in the wet forests of western Vancouver Island, Cwynar (1987) demonstrated that fires were more frequent in northwestern Washington State during the early Holocene. A warm dry climate at the study site in the early Holocene is consistent with interpretations for other parts of Vancouver Island (Hebda 1983) and the British Columbia mainland (Hebda *in press*).

Evidently, the three cave specimens from Vancouver Island represent *U. americanus*. Except for the length of LM^1 in BCPM 17198, they show no overlap in dental size with our reference sample of *U. arctos*. Differences in maxillary and mandibular toothrow lengths are especially marked among the two species. The identification is convincing because our *U. arctos* sample was designed to represent the smallest Grizzly Bears in the Pacific Northwest. According to the size trends described by Rausch (1963), size differences between our fossil specimens and extant *U. arctos* inhabiting the coastal regions of British Columbia and Alaska would be even more pronounced. Our results demonstrate the utility of dental size for discriminating modern *U. arctos* and *U. americanus* skulls. Small or immature *U. arctos* may overlap with large *U. americanus* in cranial dimensions but the two species can be unequivocally identified from molar size or toothrow length. The reliability of molar size in bear identification was tested by Gordon (1977), Verlaine-Wright et al. (1988*), and Graham (1991); however, the use of upper and lower alveolar toothrow lengths has not been described previously. These measurements should be particulary useful for identifying fossil or archaeological specimens that lack teeth.

Because dental size is an index of overall cranial size (Kurtén 1955), our early Holocene specimens provide a useful benchmark for evaluating size evolution in insular Black Bears. According to Kurtén (1959, 1963) and Gordon (1986), the evolutionary trend in *U. americanus* has been a reduction in size, with Pleistocene Black Bears significantly larger than extant forms. From an analysis of modern coastal subspecies and Pleistocene specimens from the southern United States, Gordon (1986) hypothesized that the large-sized *U. americanus* inhabiting the Queen Charlotte Islands (*U. a. carlottae*) stem from large ancestral bears that colonized these islands about 10000 BP and subsequently became isolated from mainland populations. Rather than evolving from a small mainland ancestor as predicted by the "island rule" (Case 1978; Lomolino 1985), Gordon (1986) concluded that Black Bears on the Queen Charlotte Islands demonstrate gigantism because their body size decreased at a slower rate than mainland populations.

There are two predictions from Gordon's (1986) hypothesis: 1) insular bears have decreased in size over time, and 2) extant insular populations are larger than their contemporary mainland forms. Both predictions are met by Vancouver Island Black Bears. Our data suggest that *U. americanus* inhabiting the island 9800 years ago were large relative to modern forms. Taxonomic descripions by Hall (1928) and Anderson (1945) and measurements summarized by Gordon (1986) indicate that historical *U. a. vancouveri* are larger than *U. a. altifrontalis*, the adjacent mainland subspecies. Nonetheless, in contrast to the highly isolated *U. americanus* on the Queen Charlotte Islands studied by Gordon (1986), Vancouver Island is situated only 3.5 km from the closest mainland of British Columbia, and evolutionary size trends for bears could be obscured by recurrent immigration from the coastal mainland. Despite the proximity to the mainland, Nagorsen (*in preparation**) concluded that Vancouver Island mammals differentiated at the subspecies level may be relictual species that have been isolated from mainland populations since the early postglacial. A comprehensive study of geographic variation among insular and mainland populations of Pacific Northwest *U. americanus* applying morphometric and molecular techniques is required to adequately determine patterns of size differentiation and divergence times.

Whatever the evolutionary scenario for insular gigantism, the biological factors that determine body size in bears are largely speculative. Most

researchers (Case 1978; Lomolino 1985) have assumed that body size is inherited with selection pressures associated with competition and food resources favouring large island forms. Nonetheless, climatic differences associated with the early Holocene and modern environments on Vancouver Island suggest that some of the body size differences between contemporary forms and modern and ancestral populations of *U. americanus* may reflect phenotypic responses to the environment.

Acknowledgments

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Appendix I. Specimens Examined

Locality data were taken from specimen labels. Acronyms for institutions are: BCPM, Royal British Columbia Museum, Victoria; MVZ, Museum of Vertebrate Zoology, University of California, Berkeley; NMC, Canadian Museum of Nature, Ottawa; UBC, Cowan Vertebrate Museum, University of British Columbia; USNM, United States National Museum of Natural History, Washington, D. C. M=male, F=female, U=unknown sex.

Ursus arctos

British Columbia: Bull River, 2M, 2U (MVZ); Canal Flats, 3 F (MVZ); Elk River, 1U (MVZ); Fernie 1M, 1F (MVZ); Kootenay River, 1M (MVZ); Rossland, 1U (MVZ); St. Mary's Lake, 2U (MVZ); Wasa, 1M (MVZ); White River, 1M (MVZ); Windemere, 1F (MVZ).

Ursus americanus vancouveri

British Columbia, Vancouver Island: Campbell Lake, 2F (USNM); Campbell River, 1F (NMC), 2M (USNM); Comox, 4M (NMC), 1M (USNM); Cowichan Lake, 2M, 1F (BCPM); Crown Mountain, 1M (BCPM); Douglas Peak, 1F (MVZ); Elk River, 1M (USNM); Englishman River, 1M (MVZ), 1F (UBC); Errington, 1M (MVZ), 1M (BCPM); Escoot River, 1F (USNM); Jordan River, 1M (BCPM); Kelsey Bay, 1M (BCPM), 1M (NMC); King Solomon Basin, 1M (MVZ); McIvor Lake, 1M, 1F (USNM); Nimpkish, 1M (BCPM); Port Alberni, 2M 1F (UBC); Port Hardy, 1M (USNM); Quatsino, 2M, 4F (BCPM), 2M, 2F (USNM); Quinsam River, 2M (BCPM), 2M, 1F (USNM); Sayward, 1M (BCPM); Sea Otter Cove, 1F (UBC); Shaw Creek, 1M (BCPM), 1M (NMC); Spruce River, 1F (BCPM); Woss Lake, 2M (BCPM).

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The Cougar, *Felis concolor*, in the Maritime Provinces

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The Cougar (*Felis concolor*) is a very rare animal in New Brunswick and Nova Scotia. Yet sightings of this felid are being reported with increasing frequency. Five hundred and one Cougar reports (from 1977 to 1993 inclusive) were analyzed to characterize the distribution of sightings, habitat, season and time, animal activity, vocalization, physical description and multiple sightings. Many apparently reliable observations suggest that there could be a small number of cougars, of unknown origin, in these two Maritime provinces. None are reported in Prince Edward Island.

Key Words: Cougar, *Felis concolor*, Maritimes, New Brunswick, Nova Scotia, Prince Edward Island.

The Cougar (*Felis concolor*) continues to be an enigma in eastern Canada. Recently thought to be extirpated here, sightings of this animal are being reported with increasing frequency. There is little other evidence that it occurs in the Maritimes. However, in late 1992, Cougar hair from an animal of unknown origin was verified in a scat associated with large cat tracks in central New Brunswick (Cumberland and Dempsey 1994).

The Cougar appears to have been a rare animal in the early days of settlement in New Brunswick but even that remains clouded in some uncertainty. It was considered "very rare" (Gesner 1847), or listed as "doubtful" (Adams 1873), or "not recently known" (Chamberlain 1884). While Allen (1894) and Boardman (1903) thought that the Cougar was "well-authenticated" in New Brunswick, Gagnon (1903) could find no authentic records in the province. Both Squires (1946) and Morris (1948) felt that the occurrence of the Cougar in earlier times was probable, though in very small numbers. Wright (1972) investigated cougar sightings in New Brunswick (mainly) and Nova Scotia from the 1940s to the early 1970s and concluded that the cat was still found in eastern Canada. An animal shot in Kent County, New Brunswick, in 1932 (Wright 1953) and one trapped in Maine near the Quebec border around 1938 (Wright 1961) provided some evidence of its continued existence at that time in the region.

The Cougar was probably first recorded in Nova Scotia in the 1920s, perhaps as a result of range extension following an increase in deer numbers in that province (Wright 1972). Cameron (1956) and Squires (1968) thought that the animal still occurred in most of New Brunswick and Nova Scotia, including Cape Breton Island, N.S. (Cameron 1958). *Mammals of Canada* (Banfield 1974) listed the Cougar as formerly found in New Brunswick and mainland Nova Scotia, and recently thought to be extinct, except for a few known in New Brunswick. However, its status as a resident of this province in the early 1980s seemed unlikely (Dilworth 1984). Currently the eastern Cougar is on the New Brunswick Endangered Species List. There are no past or present reports of Cougars on Prince Edward Island. This paper reviews recent Cougar sightings in the Maritimes, from essentially the early 1970s to the end of 1993.

Methods

The Canadian Wildlife Service, Atlantic Region, has been the repository for Cougar reports from government agencies and the general public throughout New Brunswick and Nova Scotia since 1977. Over 600 sightings are on file to the end of 1993. Based on verbal reports from the public and resource personnel, there also appear to be considerable numbers of Cougar sightings in the Maritimes that have gone unrecorded over the years.

Five hundred and one reports (186 from New Brunswick, 315 from Nova Scotia) were considered usable for this analysis (including five pre-1970 records). Data for each sighting, reported on standardized forms, consisted of date, time, location, observer(s), reporter, distance, viewing conditions, habitat description, animal size, description, and behaviour and track information, if available. Only those sightings with detailed first-hand information were used; 56% of the 1990-1993 observations were recorded or investigated by provincial or federal conservation officers. Seventeen percent of the total records were unusable because of the lack of supporting evidence (e.g., description of the animal seen), or obvious inaccuracies in the information provided, or because of mistaken identification, where housecats, coyotes, red foxes, bobcats, dogs, otters and bears were thought to be Cougars, as determined by the reporting conservation officers or the author. Track records alone were not considered.

The data base represents sightings made by both experienced and inexperienced observers, including hunters, trappers, wildlife technicians, foresters, veterinarians, taxidermists, and law enforcement officers, some of whom were familiar with western Cougars. This could produce a variety of biased responses; people may see what they want to see or misinterpret what they see. There is even a suggestion that only about five percent of the Cougar sightings in the northeastern United States, for example, are reliable and these may be of escaped animals (Hansen 1992). Yet experienced observers, among them wildlife professionals, in both provinces have seen and described the animal. As one R.C.M.P. officer reported, after watching two cats for over five minutes as they walked from the forest to a road where they stood and watched him, the animals were clearly visible and identifiable as Cougars. Similar Cougar sight records from Ontario (Gerson 1988) and Manitoba (Nero and Wrigley 1977) are compared with the Maritimes data where appropriate.

Results and Discussion

The number of annual Cougar sightings increased from 12 in 1978 to a high of 67 in 1991. Yearly averages of seven reports in 1975-1979, 23 in 1980-1984 and 28 in 1985-1989 continued to rise in 1990-1993 with 48. What effects the news media reports of Cougars in the Maritimes had on this increase is unknown.

Sightings came from all counties in Nova Scotia and all but one in New Brunswick (Figure 1). Those counties with the higher counts probably reflected, in part, areas of greater human activity, such as Halifax County, Nova Scotia, and the National Parks in Victoria County, Nova Scotia (Cape Breton Highlands National Park), and Albert County, New Brunswick (Fundy National Park). Half of the observations in these two counties came from the national parks and immediate surrounding areas.

Twenty one percent of the sightings were made by more than one observer; similarly Wright (1972) noted 27% for 233 New Brunswick sightings. Some reports suggested that the same Cougar had been seen independently by different observers in the same vicinity, or in the same general area over a period of days, weeks or months.

Habitat

Most of the sightings (64%) were made on or near paved or dirt roadways, either from moving or stationary vehicles. Observation times varied from a few seconds to several minutes. Sixty percent of 358 Cougars were seen in forest habitat, 23% in farmland and 17% elsewhere. However, since most of the two provinces are forested, the majority of farmland and other habitat reports are essentially within broadly wooded areas. The animals were also seen in a variety of other locales, in or on river and lake shores, beaches, blueberry fields, gravel pits, lake ice and at residences, school grounds and camp grounds.

Season and Time

Cougars were seen in every month. When 484 observations were analyzed by season, 9% were reported in winter (December, January, February), 18% in spring (March, April, May), 40% in summer (June, July, August) and 32% in fall (September, October, November). Similar seasonal values were shown for Manitoba (Nero and Wrigley 1977), Ontario (Gerson 1988) and New Brunswick prior to 1960 (Wright 1959). Seventy-two percent of the observations in the Maritimes were made between June and November, likely a reflection of increased human outdoor activity during this period.

Cougars were seen at virtually all hours of the night and day but mainly from 0600 to 2300 hours. Peak periods were 1000 and 1500 hours. Thirty percent of 432 reports were from 0700 to 1100 hours, as in Manitoba (Nero and Wrigley 1977) and 17% were between 1500 and 1700 hours, as in Ontario (Gerson 1988).

Distances of Observation

The distances at which Cougar sightings were made varied from estimates of less than 15 m to over 150 m. Twenty-five percent of 458 observations were made from 15 m or less. The median distance in each province was 45 m. Sightings greater than 150 m were occasionally made through binoculars or rifle scopes. Distances of less than 8 m from the animal were not unusual and a few estimates were less than 3 m (one with the Cougar in hand, a car strike).

Cougar Activity

Of the 396 observations where Cougar activity was recorded, 38% were seen walking, 27% running, 12% standing, 6% sitting, 5.5% leaping, 5% eating, chasing or carrying prey, 2% crouching, 2% lying down, 1% digging or scraping and <1% swimming. Ontario Cougar sightings showed similar activity values (Gerson 1988).

Cougars were seen chasing deer, a coyote, snowshoe hare, a housecat, geese and unidentified animals on ten occasions and in three instances were seen carrying a hare and housecats. One Cougar was observed eating a porcupine, another a seal pup carcass (along the seashore) and another was seen traveling from a nearby deer kill. Cougars were observed watching and stalking deer, horses, sheep, cattle and geese; their presence reportedly elicited fright responses in sheep, cattle, dogs and a saddled horse.

Cougars observed lying down were grooming or sunning, often in the middle of a paved or dirt road. A number of reports mentioned the nonchalant behavior of the animals toward humans, either not

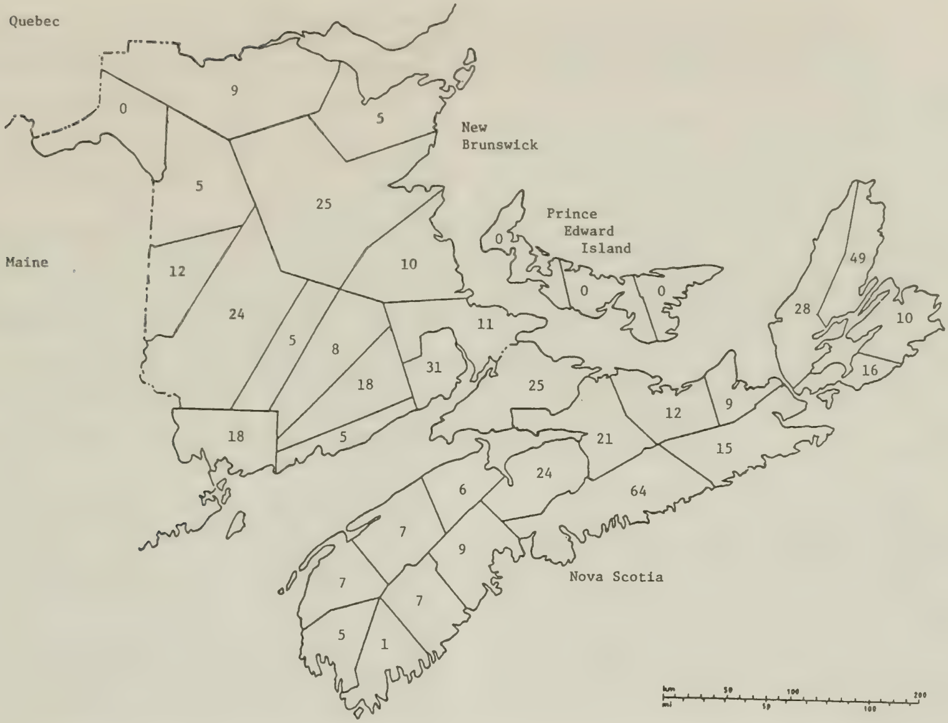

FIGURE 1. Distribution of 501 Cougar sightings, by county from three Maritime provinces, 1970–1993.

responding to their presence or more often moving away at a leisurely pace. Nero and Wrigley (1977) and Gerson (1988) also report this apparent indifference in cougar behaviour. Almost all cougars were seen on the ground, but one was observed swimming and four, including a pair, were observed in trees.

Vocalization

Cougars are usually silent (Seidensticker et al. 1973), but are capable of loud calling especially during mating time (Wright 1959). Ten reports of vocalization by observed cats described growling, snarling, hissing, screeching and screaming. When observers interrupted animals that appeared to be stalking prey, the cats growled and hissed at them; similar reactions by disturbed Cougars were noted by Nero and Wrigley (1977) and Gerson (1988).

Cougar Description

Observers described Cougars as powerful, graceful-looking animals with impressive muscle tone and sleek, long and lean bodies with cat-like faces and features, including large paws. Heavy-set shoulders and higher hind quarters were also noted. Common to all the sightings was the long tail, variously described as heavy, muscular, rope-like and thick, often with a black tip, and carried either straight out, in a long sweeping curve or curled at the tip.

Colour: The colour of 465 cougars ranged from light tan or grey to dark brown or black. Thirty-seven percent were described as brown, 18.5% tan, 18.5% black, 9% tawny, 6% grey, 2% fawn, 2% beige, 1% yellow and 6% gold or orange. Ontario cats were 35% brown and 9% black (Gerson 1988). The proportion of brown animals in both Maritime provinces was identical, but more black sightings were reported in New Brunswick (25%) than in Nova Scotia (15%). Observations in the 1990s show fewer black animals (11%) than reported in the 1970s and the 1980s. Wright (1972) listed 18 of 139 records (13%) as black Cougars between 1950 and 1970 in New Brunswick. The high proportion of black animals reported in the Maritimes is noteworthy and perplexing. Melanism in felids is rare (Robinson 1976, 1978) but has been documented in slain Cougars in Colorado (Barnes 1960) and South America (Wright 1972). A melanistic Bobcat (*Lynx rufus*) was trapped recently in New Brunswick (Tischendorf and McAlpine *in press*).

Physical dimensions: Many of the Cougar sight records included estimates of body size: shoulder height, body length, tail length, and weight. Shoulder height averaged 64 cm ± 19 cm (S.D.) (n = 351), body length, 117 cm ± 33 cm (S.D.) (369) and tail length, 80 cm ± 29 cm (S.D.) (340). Observer esti-

mates were within limits as given in the literature (Banfield 1974). Ontario sightings produced mean estimates of 67 cm, 136 cm and 75 cm respectively (Gerson 1988).

Weight estimates of 21 Maritime cats ranged from 30 to over 113 kg with a mean of 52 kg. Banfield (1974) gives adult male weights as 67 to 103 kg and adult females as 36 to 60 kg. Younger animals would be smaller.

Estimating body size and, especially, body weight of an animal under field conditions at varying distances is difficult, at best, even for the most experienced observer. As such, the values presented here, as estimated by a variety of experienced and inexperienced observers, have inherent biases that require caution in their use or interpretation. The hundreds of estimated measurements, however, do seem consistent with those of large cats.

Pairs and Young

Cougars are generally solitary animals except during breeding. Twenty sightings of two or more cats seen together were reported in the Maritimes. Nine of these were of an adult with one or two kittens (seven in Nova Scotia, two in New Brunswick). At least four other reports were of different size animals in pairs.

Conclusion

Many apparently reliable observations suggest that there could be a small number of Cougars in New Brunswick and Nova Scotia. The wide distribution of sightings throughout the region could imply that animals other than escaped captive or released cats are at large. Cougars could possibly be moving into the region from further west. Only recently have there been specimens (of unknown origin) collected in the field in Ontario and Quebec (B. Johnson, personal communication). There are not many captive Cougars registered in both provinces; less than 12 are currently known in zoos, wildlife parks or as pets. Illegally possessed animals would likely constitute a very small number. There may have been escaped Cougars at large in past years but this remains unconfirmed. However, these very few animals would not account for the increase in sightings over the region. Whether the Cougars reported are of the eastern subspecies (*F. c. couguar*) is speculation since no recent confirmed wild specimens have been examined.

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A New Agromyzid (Diptera) Leaf-miner of Mountain Holly (*Nemopanthus*, Aquifoliaceae) from the Avalon Peninsula, Newfoundland

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Phytomyza ***nemopanthi*** Griffiths & Piercey, a leaf-miner of *Nemopanthus mucronata* (L.) Trel. (mountain holly, Aquifoliaceae) is described from Newfoundland. This new species belongs to the *Phytomyza ilicis* group containing seven previously described species, all miners of *Ilex* spp. (Aquifoliaceae).

Key Words: *Phytomyza ilicus* group, *Phytomyza nemopanthi*, Agromyzidae, *Nemopanthus*, Aquifoliaceae, Newfoundland.

The holly leaf-miners (*Phytomyza ilicis* group; Diptera, Agromyzidae) infesting various species of *Ilex* (Aquifoliaceae) in North America were revised by Kulp (1968), who described five new species in addition to the previously known *Phytomyza ilicicola* Loew and *P. ilicis* Curtis (the latter introduced from Europe). Subsequent works by Spencer (1969, 1973, 1986, 1990) contain supplementary information and figures, but no additional species. The reported host associations of the seven species (after Kulp and Spencer) are as follows:

Phytomyza ilicis Curtis: *Ilex aquifolium* L.
P. ilicicola Loew: *I. opaca* Ait., *I. opaca* Ait. × *I. myrtifolia* Walt., and *I. aquifolium* L.
P. ditmani Kulp: *I. decidua* Walt. and *I. serrata* Thunb.
P. glabricola Kulp: *I. glabra* (L.) A. Gray
P. opacae Kulp: *I. opaca* Ait., *I. cumulicola* Small, and *I. aquifolium* L.
P. verticillatae Kulp: *I. verticillata* (L.) A. Gray.
P. vomitoriae Kulp: *I. vomitoria* Ait.

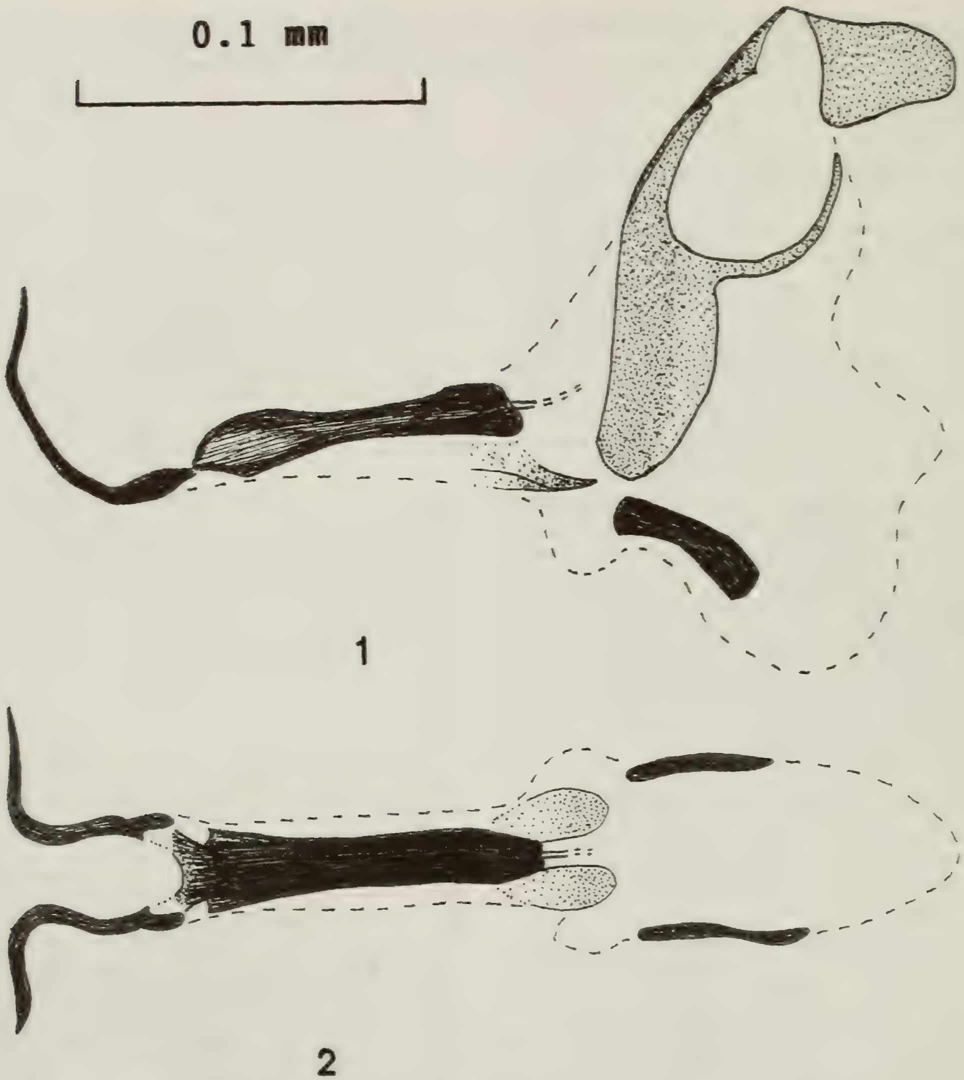
During the summer of 1991, one of us (M. D. Piercey-Normore) collected the immature stages of a member of the *Phytomyza ilicis* group in large numbers in the leaves of Mountain Holly, *Nemopanthus mucronata* (L.) Trel. (Aquifoliaceae), on the northeast Avalon Peninsula in Newfoundland. The 91 adult flies reared from these samples are morphologically homogenous and represent an undescribed species. While the male terminalia of this new species are closest to those of *P. ilicicola* Loew, the anterior spiracles of the third instar larva (and puparium) do not agree with that species, but are two-horned as in *P. ditmani* Kulp, *P. opacae* Kulp and *P. verticillatae* Kulp. Bionomically the new species differs from *P. ilicicola* in exploiting a deciduous host and forming puparia in autumn. It is remarkable that the larvae are able to complete their feeding in "green islands" in fallen leaves, something which does not seem to have been previously reported for agromyzid larvae although well-known for certain non-dipterous leaf-mining larvae (see Hering 1951). According to Kulp (1968), larvae of *P. ilicicola* on evergreen hollies pupate between January and April.

Two of the above miners of *Ilex* spp., *Phytomyza ditmani* Kulp and *P. verticillatae* Kulp, exploit deciduous hosts, but morphologically they are not as close to the new species as is *P. ilicicola* Loew. So the shift from evergreen to deciduous hosts (or vice versa) must have occurred more than once in the evolution of the *Phytomyza ilicis* group. While the association of a member of this group with *Nemopanthus* is formally an extension of the host range to a new genus, this extension is hardly surprising in view of the close relationship between *Nemopanthus* and *Ilex*. The absence of any overlap in the host associations between deciduous and evergreen Aquifoliaceae suggests that such bionomic differences may have played an important role in the speciation of the flies, through selection for larval feeding on different hosts at different times of the year.

Nemopanthus mucronata (L.) Trel. is a tall deciduous shrub found in moist (especially Black Spruce) forest in Eastern Canada and adjacent parts of the United States (from Minnesota and Ontario east to Newfoundland and south to Illinois and Virginia). It ranges further north than any of the native species of *Ilex*.

The terminology and descriptive format used in this paper follow that in the series "Studies on boreal Agromyzidae". See the first paper in that series (Griffiths 1972) for explanation.

Adults of the new species here described will run to *Phytomyza ilicicola* Loew in the keys to the Agromyzidae of Canada and the United States published by Spencer (1969, 1986), from which they can be reliably distinguished only by details of the



FIGURES 1–2. *Phytomyza nemopanthi* n. sp., holotype ♂: 1, aedeagus in left lateral view; 2, distal section and medial lobe of aedeagus in ventral view.

aedeagal structure. Identification of the immature stages will be unproblematic, since no other dipterous leaf-miners are known from *Nemopanthus*.

Phytomyza ***nemopanthi*** Griffiths & Piercey, new species

Adult. — Head with orbits not or only slightly projecting above eye in lateral view; genae in middle 0.15 – 0.2 times eye height; eyes with only sparse inconspicuous pubescence. Frons at level of anterior ocellus 1.5 – 1.8 times width of eye. Two pairs of posteriorly directed upper orbital setae (ors) of about equal length (posterior ors closer to anterior than to inner vertical seta); two pairs of inwardly directed lower orbitals (ori) (anterior shorter than posterior); 2–4 proclinate orbital setulae. Peristomal margin with vibrissa and 3–4 upcurved peristomal setulae (in some specimens also 1–2 short genal setulae above vibrissa). Third antennal article rounded distally, about as long as high, with short pubescence.

3 + 1 dorsocentral setae; acrostichal setulae numerous, in 4–6 rows anteriorly; presutural intra-alar setulae (ia) numerous; 6–12 postsutural ia; inner postalar seta third to half as long as outer.

Lower cross-vein (m-m) absent. Costal ratio mg_2/mg_4: ♂, 2.4–3.0 (mean 2.63 ± 0.16, n = 25); ♀, 2.25–3.2 (mean 2.83 ± 0.22, n = 48). Wing length: ♂, 1.75–2.05 mm (mean 1.94 ± 0.07 mm, n = 23);

♀, 1.75–2.4 mm (mean 2.17 ± 0.11 mm, n = 43).

Colour largely dark. Center of frons dark brown; genae brownish. Labella yellowish. Thorax rather densely grey-dusted over almost entirely dark ground-colour, with paler coloration along seams of notopleural and mesopleural sutures but only obscure indications of paler coloration in notopleural depression and on corners of humeral and postalar calli. Wing base and squamae yellowish, the latter with tawny to brownish fringe. Coxae, trochanters, femora and tarsi largely dark brown; tips of femora and most of tibiae orange-yellow to yellow-brown. Abdomen largely brown to dark brown, but with lateral margins of tergites and in female also posterior margin of 6th tergite narrowly yellowish. Basal cone of ovipositor (♀) entirely finely dusted.

Male terminalia similar to those of other members of the *Phytomyza ilicis* group (especially those of *P. ilicicola* Loew), from which they differ with respect to details of the aedeagal structure (Figures 1-2): basal sclerites broad distally; sclerites of medial lobe ("hypophallus") strongly pigmented, scarcely expanded distally, similarly developed on each side; paramesophalli weakly differentiated (pigmented only basally); mesophallus long and almost parallel-sided in ventral view; distiphallic tubules more strongly bent outwards than in all other species of this group (at right angles or even slightly reflexed on their distal halves in dorsal/ventral view).

Puparium and third instar larva. — Similar to those of *P. ditmani* Kulp, *P. opacae* Kulp and *P. verticillatae* Kulp (see Kulp 1968, Figure 7), with anterior spiracles two-horned, bearing 16–20 bulbs in total (8–10 on each horn) (Figure 4); posterior spiracles with 12–14 bulbs in irregular ellipse. Puparia deep yellow to yellow-brown, 1.9–2.2 mm long.

Mine. — Larvae leaf-miners on *Nemopanthus mucronata* (L.) Trel. (Aquifoliaceae), English name "mountain holly". Mines beginning as a narrow linear channel on lower surface of leaf, then crossing to upper surface and abruptly widening (Figure 3); the lower surface channels may extend for the entire length of the leaf (sometimes even twice) before crossing to the upper suface. Faeces deposited as closely spaced fine black particles along one side or toward center of early mine channel, later in larger more widely spaced pellets as the larvae becomes older and the mine widens. Puparia formed inside the mine, with their anterior spiracles projecting through the leaf epidermis (normally on the lower surface) (Figure 4).

In leaves which fell prior to puparium formation, a green area (on which the larva continued to feed) was often observed around the mine.

Phenology. — In 1991, young leaves of mountain holly were observed to contain adult feeding punctures from June 17 until August 13, when the first early mines were seen on the undersides of the leaves. Older mines with channels on the uppersides

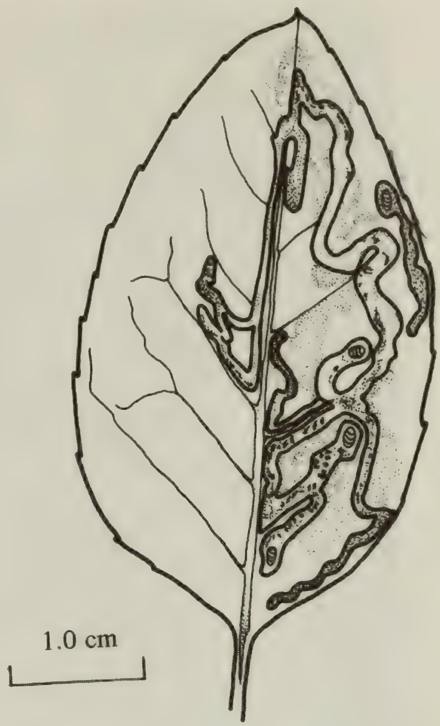


FIGURE 3. Leaf of *Nemopanthus mucronata* (L.) Trel. (upper surface) showing mines and puparia of *Phytomyza nemopanthi* n. sp.

were first noted on September 27. Yellowing of the leaves began on October 4, and most leaves had fallen by October 25. Fallen leaves with mines contained both puparia and larvae, which were able to complete their feeding in "green islands".

Puparia kept at 4°C for three months produced adults the following spring (mainly in early April), but we believe that emergence in the wild must occur somewhat later since feeding punctures were not observed on the host-plant prior to June 17.

Type Designation. — Holotype ♂, 20♂♂ 34♀♀ paratypes reared from larvae and puparia collected 27.ix–10. x .91 in leaves of *Nemopanthus mucronata* (L.) Trel., Cochrane Pond Road, Avalon Peninsula, Newfoundland, adults emerged by 2.iv.92; 11♂♂ 21♀♀ paratypes, same data, emerged by 10.iv.92; 1♂ 1♀ paratypes, same data, emerged by 13.iv.92. 2♀♀ paratypes reared from same plant, Goulds, Avalon Peninsula, Newfoundland, emerged 16.iii & 2.iv.92. All material collected and reared by M. D. Piercey-Normore. Material divided between Canadian National Collection, Ottawa (holotype, 2♂♂ 3♀♀ paratypes), University of Alberta, Edmonton (3♂♂ 3♀♀ paratypes) and Department of Biology of Memorial University of Newfoundland (remaining material).

FIGURE 4. Photograph of anterior spiracles of puparium of *Phytomyza nemopanthi* n. sp. projecting through lower surface of leaf of *Nemopanthus mucronata* (L.) Trel.

Acknowledgments

We are indebted to D. J. Larson for inspiring one of us (M. D. Piercey-Normore) with an interest in leaf miners, and to K. N. Egger for providing her with financial support. K. A. Spencer kindly provided advice in correspondence.

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Catalogue des algues d'eau douce du Québec, Canada

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Poulin, Michel, Paul B. Hamilton, et Marc Proulx. 1995. Catalogue des algues d'eau douce du Québec, Canada. Canadian Field-Naturalist 109(1): 27–110.

Nous présentons une liste des espèces d'algues qui ont été rapportées dans les systèmes aquatiques dulcicoles de la province de Québec depuis les débuts même de l'herborisation phycologique. Les régions québécoises les plus fortement inventoriées sont Montréal, les Laurentides, Trois-Rivières et le territoire de la baie de James. La flore consiste en 2 947 taxons répartis en 419 genres avec les principales divisions d'algues représentées dans cette liste par les Chlorophyta (1692 taxons), les Bacillariophyta (646 taxons) et les Cyanophyta (269 taxons) qui, ensemble, contribuent à 88% du total. Seize nouvelles combinaisons nomenclaturales sont proposées: *Brachysira zellensis* var. *linearis* (Østr.) Poulin, *Catenochrysis synuroidea* (Prowse) Poulin, *Diadesmis contenta* var. *parallela* (Petersen) Hamilton, *Fragilariforma virescens* var. *capitata* (Østr.) Poulin, *Gomphoneis olivacea* var. *calcarea* (Cleve) Poulin, *Pseudostaurosira brevistriata* var. *inflata* (Pant.) Poulin, *Sellaphora pupula* f. *capitata* (Skvortzow & Meyer) Poulin, *Sellaphora pupula* var. *elliptica* (Hust.) Poulin, *Sellaphora pupula* var. *mutata* (Krasske) Poulin, *Staurosira construens* var. *triundulata* (Reichelt ex Hartz & Østr.) Hamilton, *Staurosirella leptostauron* var. *dubia* (Grun.) Poulin, *Staurosirella pinnata* var. *lancettula* (Schumann) Poulin, *Urosolenia eriensis* var. *morsa* (W. & G.S. West) Poulin, *Xanthidium bucerium* (Ir.-Mar.) Poulin, *Xanthidium octocorne* var. *mamillatum* (Scott & Grönbl.) Poulin, et *Xanthidium octocorne* var. *tenue* (Ir.-Mar.) Poulin.

A catalogue of the freshwater algae is reported from the Province of Québec since its first phycological sampling. The most highly botanized regions are Montréal, Laurentides, Trois-Rivières and James Bay territory. The flora consists of 2947 taxa belonging to 419 genera, with the main algal divisions represented by the Chlorophyta (1 692 taxa), Bacillariophyta (646 taxa) and Cyanophyta (269 taxa) accounting for 88% of the total. Sixteen new nomenclatural combinations are proposed: *Brachysira zellensis* var. *linearis* (Østr.) Poulin, *Catenochrysis synuroidea* (Prowse) Poulin, *Diadesmis contenta* var. *parallela* (Petersen) Hamilton, *Fragilariforma virescens* var. *capitata* (Østr.) Poulin, *Gomphoneis olivacea* var. *calcarea* (Cleve) Poulin, *Pseudostaurosira brevistriata* var. *inflata* (Pant.) Poulin, *Sellaphora pupula* f. *capitata* (Skvortzow & Meyer) Poulin, *Sellaphora pupula* var. *elliptica* (Hust.) Poulin, *Sellaphora pupula* var. *mutata* (Krasske) Poulin, *Staurosira construens* var. *triundulata* (Reichelt ex Hartz & Østr.) Hamilton, *Staurosirella leptostauron* var. *dubia* (Grun.) Poulin, *Staurosirella pinnata* var. *lancettula* (Schumann) Poulin, *Urosolenia eriensis* var. *morsa* (W. & G.S. West) Poulin, *Xanthidium bucerium* (Ir.-Mar.) Poulin, *Xanthidium octocorne* var. *mamillatum* (Scott & Grönbl.) Poulin, and *Xanthidium octocorne* var. *tenue* (Ir.-Mar.) Poulin.

Mots clés: Algues d'eau douce, Chlorophyta, Desmidiaceae, Bacillariophyta, Cyanophyta, Québec.

Cette liste d'énumération représente la compilation des algues d'eau douce recensées sur le territoire de la province de Québec et elle s'inscrit comme une suite logique de travaux similaires menés en différentes régions canadiennes telles au Labrador (Duthie et al. 1975; Duthie et Ostrofsky 1975a, b, 1978; Duthie et al. 1976), en Ontario (Duthie et Socha 1976), en Colombie britannique (Stein et Borden 1979) et dans les Territoires du nord-ouest (Sheath et Steinman 1982), visant ultimement la reconnaissance de la flore cryptogamique des eaux douces canadiennes.

Ce répertoire vise, tout d'abord, à accroître sensiblement nos connaissances sur le patrimoine floristique naturel des milieux dulcicoles du Québec et, par le fait même, à mettre à jour la diversité biologique de cette importante flore aquatique, surtout microscopique, mais auparavant méconnue à l'échelle provinciale (Gouvernement du Québec 1992). Ces données phycologiques pour le Québec, couplées à celles déjà disponibles pour trois autres provinces canadiennes ainsi qu'un territoire, contribuent à identifier clairement la diversité biologique de cette flore microscopique recensée à partir de différents habitats aquatiques dulcicoles et à fournir une liste exhaustive des algues d'eau douce retrouvées à l'échelle du Canada.

Ce catalogue procure également une base de comparaison valable avec les listes floristiques actuelles ou futures dont plusieurs espèces peuvent éventuellement être soumises à diverses formes de pollution ou de perturbation environnementale. Une meilleure connaissance de cette microflore dulcicole peut nous renseigner sur la nuisance exercée par certains taxons sur des bassins aquatiques réservés à la pisciculture ou encore sur l'odeur nauséabonde se dégageant de certains cours d'eau. Finalement, cette liste se veut un document de travail pour des études futures en limnologie ou autres disciplines connexes, ou encore dans le cadre d'études de la répartition phytogéographique.

Les références bibliographiques citées dans cette liste comprennent 129 documents qui incluent surtout des publications scientifiques à contenu taxonomique quoique plusieurs sont plus spécialement d'intérêt éco-physiologique, des rapports de recherche inédits d'institutions gouvernementales provinciale et fédérale ou d'agences de consultation, des mémoires à la maîtrise et au doctorat, des collections consignées sous la forme de manuscrits inédits et une base informatisée de données phycologiques.

Les régions du Québec les plus fortement inventoriées comprennent Montréal, les Laurentides, Trois-Rivières, le territoire de la baie de James, le Parc de la Gatineau, la Côte-Nord et le lac Saint-Jean, avec plus de 60% des publications. D'autres documents ont aussi couvert des régions telles la Gaspésie, le Nouveau-Québec, l'île d'Anticosti et les Iles-de-la-Madeleine.

La flore algologique des eaux douces de la province de Québec s'élève donc maintenant à 2947 taxons (espèce, sous-espèce, variété et forme) répartis en 419 genres. Les principales divisions d'algues représentées dans cette liste sont les Chlorophyta (1692 taxons, 57% du total), incluant une très forte représentation par la famille des Desmidiaceae (1278 taxons), les Bacillariophyta (646 taxons, 22% du total) et les Cyanophyta (269 taxons, 9% du total), suivies des divisions plus faiblement représentées telles les Chrysophyta (152 taxons), les Euglenophyta (85 taxons), les Pyrrophyta et les Xanthophyta (34 taxons), les Cryptophyta (20 taxons), les Rhodophyta (9 taxons), les Haptophyta (4 taxons) et les Raphidophyta (2 taxons). Plusieurs documents cités n'ont toutefois pas inclus l'identification des spécimens à un niveau sous-générique si bien que 59 genres, soit 14% du total, sont consignés sans aucune mention d'espèce, mais cette information est importante en soi puisqu'elle sert à démontrer la diversité des écosystèmes de la province.

Dans la liste, le nom valide le plus récent de chacun des taxons est retenu alors que les noms désuets ont été placés en synonymie et peuvent être facilement repérés par le symbole "égal" (=). Les cas pour lesquels le statut ou la position taxonomique est incertaine peuvent être facilement détectés par un point d'interrogation (?) placé devant le nom du taxon concerné. Les nombres apparaissant à la suite de chacun des taxons refèrent aux documents publiés et inédits de la litérature citée qui se retrouve à la toute fin de la liste d'interrogation. À l'occasion, des erreurs typographiques ou nomenclaturales relevées dans les documents originaux ont été inscrites sans modification entre parenthèses à la suite des nombres référant aux sources bibliographiques. Finalement, le lecteur retrouvera en appendice des annotations se rapportant à des problèmes ou des précisions de nature nomenclaturale identifiable dans la liste d'énumération par des chiffres placés en exposant.

La nomenclature a été mise à jour principalement à l'aide des travaux d'Huber-Pestalozzi (1955), Forest (1956), Desikachary (1959), Wood et Imahori (1964-65), Bourrelly (1966b, 1968, 1985), Fott (1968), Komárkova-Legnerová (1969), Prescott (1973), Prescott et al. (1972, 1975, 1977, 1981, 1982), Ettl (1978), Rieth (1980), Croasdale et al. (1983), Komárek et Fott (1983), Mrozinska (1985), Starmach (1985), Hartley (1986), Ettl et Gärtner (1988), Hegewald et Silva (1988), Compère (1989), Popovsky et Pfiester (1990), et Round et al. (1990). Nous prions les lecteurs avertis de nous signaler toute erreur de nomenclature oubliée dans cette liste.

Malheureusement dans le cadre du présent travail, il nous est impossible de fournir une base de comparaison valable avec les études antérieures réalisées dans les autres régions canadiennes. La systématique et la taxonomie ont évolué tellement rapidement au cours des vingt dernières années qu'il devient pratiquement impossible de comparer les systèmes de classification d'antan avec ceux d'aujourd'hui. Un autre point à considérer lequel apporte un certain biais à ces comparaisons concerne la concentration d'études relatives à certains groupes taxonomiques ciblés selon les intérêts même du scientifique. Ainsi, pour le Québec, il est aisé de constater que les Desmidiaceae sont très majoritairement représentées étant donné la très grande multitude de publications produites par le frère Irénée-Marie. Ce genre d'information apporte un biais dans le traitement des données lorsqu'elles sont comparées avec d'autres régions où un groupe taxonomique différent a été favorisé. Il serait intéressant d'explorer davantage ce genre de comparaison entre les flores algales dulcicoles des différentes régions canadiennes inventoriées, ce qui devrait être le sujet d'une prochaine publication.

Chlorophyta
Charophyceae
Charales

Chara braunii f. *schweinitzii* (A. Br.) Wood
=*C. schweinitzii* A. Br.
115
Chara globularis Thuill.
=*C. fragilis* Desv.
35, 92
Chara vulgaris L.
92
=*C. foetida* A. Br.
122
Chara vulgaris f. *contraria* (A. Br. ex Kütz.) Wood
=*C. contraria* A. Br. ex Kütz.
35, 92, 115

Chara vulgaris f. *intumescens* (Robinson) Wood
=*C. intumescens* Robinson
115
Chara spp.
29, 99, 100, 124
Nitella flexilis (L.) Ag.
=*N. opaca* (Bruz.) Ag.
92
Nitella spp.
7, 92, 100

Chlorophyceae

Chaetophorales

Aphanochaete globosum (Nordst.) Klebahn
94
Aphanochaete polychaete (Hansg.) Fritsch
20, 21, 121
Aphanochaete repens A. Br.
5, 6, 20, 21, 90, 92, 97, 121, 129
Aphanochaete sp.
20
Chaetophora elegans (Roth) C. Ag.
79, 121
Chaetophora endiviaefolia C. Ag.
79
Chaetophora incrassata (Huds.) Haz.
6, 92, 101, 121
Chaetophora pisiformis (Roth) C. Ag.
6, 97
Chaetophora tuberculosa Hook
79
Chaetophora spp.
6, 20, 36, 92, 93, 121, 124, 126
Draparnaldia mutabilis [1](Roth) Bory
=*D. acuta* (C. Ag.) Kütz.
20
=*D. glomerata* (Vauch.) C. Ag.
40, 92, 93, 96, 97, 129
=*D. platizonata* Haz.
92
=*D. plumosa* (Vauch.) C. Ag.
36, 79, 100, 121
Draparnaldia spp.
6, 20, 21, 36, 92
Ectochaete spp.
29, 99, 124
Entocladia polymorpha (G.S. West) G.M. Sm.
121
Gongrosira spp.
20, 21, 121
Microthamnion kuetzingianum Näg.
6, 20
Microthamnion strictissimum Rabenh.
5, 20, 21, 93
Microthamnion spp.
20, 29, 92, 99, 124
Pseudendoclonium basiliense var. *brandii* Vischer
107
Pseudendoclonium sp.
121
Stigeoclonium aestivale (Haz.) Coll.
20, 101
Stigeoclonium condensatum (Hass.) Kütz.
=*Draparnaldia condensata* Hass.
79
Stigeoclonium lubricum (Dillw.) Kütz.
121
Stigeoclonium nanum (Hass.) Kütz.
=*Draparnaldia nana* Hass.
79
Stigeoclonium stagnatile (Haz.) Coll.
96
Stigeoclonium tenue (C. Ag.) Kütz.
20, 97, 101, 121
=*Draparnaldia tenuis* C. Ag.
79
Stigeoclonium spp.
20, 36, 87, 88, 92, 93, 111, 121, 124
Thamniochaete huberi Gay
20, 21
Ulvella sp.
121

Chlorococcales

Acanthosphaera spp.
22, 23, 39, 124
Actinastrum gracillimum G.M. Sm.
20, 21, 100
Actinastrum hantzschii Lagerh.
24, 25, 27, 28, 88, 116, 121, 124
Actinastrum hantzschii var. *fluviatile* Schröder
24, 88
Actinastrum spp.
39
Ankistrodesmus bibraianus[2](Reinsch) Kors.
=*Selenastrum bibraianum* Reinsch
20, 21, 97, 100, 124
Ankistrodesmus falcatus (Corda) Ralfs
5, 6, 20, 21, 22, 23, 26, 27, 28, 29, 31, 39, 40, 76, 90, 92, 93, 94, 97, 98, 99, 100, 106, 109, 110, 111, 112, 116, 118, 121, 124, 125, 126
=*Raphidium falcatum* (Corda) Cooke
101
=*A. falcatus* var. *radiatus* (Chodat) Lemm.
20, 21, 124
Ankistrodesmus fasciculatus (Lundb.) Kom.-Legn.
=*Quadrigula fasciculata* Lundb.
5, 20, 21, 29, 99, 124
Ankistrodesmus gelifactum[3](Chodat) Bourrelly
5, 124
Ankistrodesmus gracilis (Reinsch) Kors.
=*Selenastrum gracile* Reinsch
20, 21, 24, 25, 88, 97, 124
Ankistrodesmus spiralis (Turn.) Lemm.
20, 21, 27, 28, 76, 77, 92, 93, 94, 99, 117, 118, 124
=*A. falcatus* var. *spiralis* (Turn.) G.S. West
20

Ankistrodesmus spp.
20, 22, 23, 29, 76, 78, 95, 99, 105, 124, 125
Botryococcus braunii Kütz.
5, 20, 21, 22, 39, 92, 94, 97, 106, 124, 126
Botryococcus spp.
22, 23, 116, 121, 124, 126
Botryosphaerella sudetica (Lemm.) Silva
=*Botryosphaera sudetica* (Lemm.) Chodat
1, 21, 88
=*Botryococcus sudeticus* Lemm.
106
Cerasterias irregulare G.M. Sm.
121
Cerasterias sp.
124
Characiellopsis skujae (Fott) Komárek
=*Characium obtusum* A. Br.
20, 21, 121 (*C. obtusatum*), 124, 125, 126
Characium conicum(4) Kors.
=*C. naegelii*(5) A. Br.
124
Characium ensiforme Hermann
=*C. ambiguum*(6) Hermann
20, 21, 97, 121
Characium ornithocephalum var. *harpochytriiforme* Printz
=*C. falcatum* Schröder
20, 121
Characium ornithocephalum var. *pringsheimii* (A. Br.) Komárek
=*C. pringsheimii* A. Br.
121
Characium rabenhorstii(7) De Toni
124
Characium rostratum Rabenh. ex Printz
20, 21, 121
Characium sieboldii A. Br.
101
Characium spp.
20, 121, 124, 125, 126
Chlorella pyrenoidosa Chick
77
Chlorella vulgaris Beijerinck
96, 97, 124
Chlorella spp.
6, 20, 109, 110, 112, 118, 121
Chlorolobion braunii (Näg.) Komárek
=*Monoraphidium braunii* (Näg.) Kom.-Legn.
121
=*Ankistrodesmus braunii* (Näg.) Brunnth.
20
Chlorolobion saxatile (Kom.-Legn.) Komárek
=*Monoraphidium saxatile* Kom.-Legn.
121
Chondrosphaera spp.
29, 99, 124
Closteriopsis longissima (Lemm.) Lemm.
106
Closteriopsis longissima var. *tropica* W. & G.S. West
20
Closteriopsis spp.
20, 124
Coelastrum cambricum Archer
1, 20, 21, 23, 24, 25, 27, 28, 88, 92, 97, 98, 100, 110, 112, 121, 124
Coelastrum microsporum Näg.
1, 20, 21, 24, 25, 29, 88, 90, 92, 94, 97, 98, 99, 111, 116, 121, 124
Coelastrum reticulatum (Dang.) Senn
94, 100
Coelastrum sphaericum Näg.
121
Coelastrum spp.
39, 82, 95, 99, 116, 117, 118, 124, 126
Coenochloris pelagica (Teil.) Fott
=*Eutetramorus lundii* Bourrelly
88, 98
Coenocystis subcylindrica Kors.
5
Coenocystis spp.
29, 99, 124
Crucigenia fenestrata (Schmidle) Schmidle
110, 112
Crucigenia quadrata Morr.
27, 28, 97, 109, 121, 124, 126
Crucigenia tetrapedia (Kirchn.) W. & G.S. West
20, 21, 22, 23, 27, 28, 39, 98, 99, 105, 106, 109, 110, 111, 112, 116, 117, 121, 124, 126
Crucigenia spp.
20, 22, 23, 29, 39, 99, 106, 121, 124, 126
Crucigeniella apiculata (Lemm) Komárek
=*Crucigenia apiculata* (Lemm.) Schmidle
124
Crucigeniella crucifera (Wolle) Komárek
=*Crucigenia crucifera* (Wolle) Coll.
20, 27, 28
Crucigeniella rectangularis (Näg.) Komárek
=*Crucigenia rectangularis* (Näg.) Gay
20, 21, 22, 31, 39, 92, 97, 101, 110, 112, 116, 121, 124
Crucigeniella truncata (G.M. Sm.) Komárek
=*Crucigenia truncata* G.M. Sm.
116 (sous *C. apiculata* var. *truncata*), 124 (aussi sous *C. apiculata* var. *truncata*), 126
Dicellula spp.
29, 99, 124
Dictyosphaerium ehrenbergianum Näg.
20, 21, 106, 121, 124
Dictyosphaerium pulchellum Wood
1, 5, 20, 21, 24, 25, 27, 28, 77, 78, 88, 92, 97, 98, 100, 116, 117, 118, 121, 124, 126
Dictyosphaerium spp.
20, 22, 23, 29, 39, 99, 118, 121, 124, 126
Dimorphococcus cordatus Wolle
20, 100

Dimorphococcus lunatus A. Br.
1, 20, 21, 88, 97, 98, 100, 110, 112, 121, 124
Dispora spp.
39
Ducellieria chodatii (Ducellier) Teil.
20, 21, 76, 77
=*Coelastrum chodati* Ducellier
99, 117, 124
Elakatothrix gelatinosa Wille
5, 22, 27 (*Elakothrix gelatinosa*), 28, 39, 76, 77, 94, 106, 121
Elakatothrix viridis (Snow) Printz
94, 100
Elakatothrix spp.
20, 22, 39
Eremosphaera viridis De Bary
20, 21, 92, 96
Eremosphaera sp.
20
Euastropsis richteri (Schmidle) Lagerh.
124, 126
Excentrosphaera viridis Moore
20, 22, 23
Franceia spp.
22, 39
Fusola viridis Snow
=*Ankistrodesmus viridis* (Snow) Bourrelly
124
Glaucocystis nostochinearum (Itz.) Rabenh.
5, 20, 92, 94
Glaucocystis oocystiformis Prescott
20
Glaucocystis spp.
29, 124
Gloeotaenium loitlesbergerianum Hansg.
94
Golenkinia paucispina W. & G.S. West
87, 100
=*Micractinium paucispinosa* (W. & G.S. West) Wille
27, 28
Golenkinia radiata Chodat
1, 88, 111, 124
Golenkinia spp.
20, 22, 39, 87, 118, 121, 124, 126
Hydrianum spp.
29, 99, 124
Hydrodictyon reticulatum (L.) Lagerh.
1, 6, 24, 25, 88, 97, 98, 101, 111, 121
Kirchneriella arcuata G.M. Sm.
5
Kirchneriella contorta (Schmidle) Bohlin
5, 20, 21, 27, 28, 121, 124, 126
Kirchneriella irregularis (G.M. Sm.) Kors.
=*K. lunaris* var. *dianae* Bohlin
5, 77
=*K. lunaris* var. *irregularis* G.M. Sm.
20, 27, 28
Kirchneriella lunaris (Kirchn.) Möb.
1, 20, 21, 23, 29, 76, 88, 94, 97, 98, 99, 100, 101, 107, 110, 112, 117, 121, 124
Kirchneriella obesa (W. West) Schmidle
5, 6, 20, 21, 24, 25, 76, 77, 88, 100, 110, 112, 118, 124
Kirchneriella subcapitata Kors.
=*K. obesa* var. *major* (Bernard) G.M. Sm.
20, 21, 29, 94, 99, 124
Kirchneriella spp.
20, 23, 39, 124, 126
Korshikoviella graciliceps (Lamb.) Silva
5
Lagerheimia ciliata (Lagerh.) Chodat
=*Chodatella ciliata* (Lagerh.) Lemm.
1, 88
Lagerheimia genevensis (Chodat) Chodat
=*Chodatella quadriseta* Lemm.
121
Lagerheimia spp.
22, 23
Macrochloris radiosa Ettl & Gärtner
=*Chlorococcum infusionum* (Schrank) Menegh.
97
Micractinium bornhemiense (Conrad) Kors.
=*Errerella bornhemiensis* Conrad
1, 24, 25, 88, 98
Micractinium pusillum Frés.
1, 24, 25, 88, 98, 99, 110, 111, 112, 117, 124
Micractinium sp.
111
Monoraphidium arcuatum[(8)](Kors.) Hindák
=*Ankistrodesmus arcuatus* Kors.
29, 99, 124
Monoraphidium contortum (Thur.) Kom.-Legn.
121 (*M. contorium*)
=*Ankistrodesmus falcatus* var. *spirilliformis* G.S. West
20, 27, 28
Monoraphidium convolutum (Corda) Kom.-Legn.
=*Ankistrodesmus convolutus* Corda
121
Monoraphidium griffithii (Berk.) Kom.-Legn.
121
=*Ankistrodesmus falcatus* var. *acicularis* (A. Br.) G.S. West
76, 77, 92, 97, 118
=*Raphidium falcatum* var. *aciculare* A. Br.
101
Monoraphidium komarkovae Nyg.
=*M. setiforme* (Nyg.) Kom.-Legn.
121
Monoraphidium minutum (Näg.) Kom.-Legn.
121
=*Selenastrum minutum* (Näg.) Coll.
22, 23, 27, 28, 76, 77, 100, 101, 106, 118
Monoraphidium mirabile (W. & G.S. West) Pankow
=*Ankistrodesmus falcatus* var. *mirabilis* (W. &

G.S. West) G.S. West
28, 77
Nephrocytium agardhianium Näg.
1, 27, 28, 88, 92, 97
Nephrocytium limneticum (G.M. Sm.) G.M. Sm.
5, 20, 27, 28, 121
Nephrocytium lunatum W. West
20, 21, 97
Nephrocytium spp.
22, 23
Oocystis borgei Snow
20, 21, 76, 77
Oocystis elliptica W. West
92, 129
Oocystis gloeocystiformis Borge
27, 28, 121
Oocystis lacustris Chodat
77, 100
Oocystis parva W. & G.S. West
27, 28, 94, 100
Oocystis pusilla Hansg.
106, 118
Oocystis pyriformis Prescott
76
Oocystis solitaria Wittr.
97
Oocystis submarina Lagerh.
76, 77, 97
Oocystis spp.
20, 22, 23, 24, 29, 39, 40, 76, 78, 88, 99, 106, 109, 110, 111, 112, 118, 121, 124, 125, 126
Oonephris obesa (W. West) Fott
=*Nephrocytium obesum* W. West
97
Oophila amblystomatis[9] Lamb. ex Printz
20, 21
Palmella sp.
20
Palmodictyon varium (Näg.) Lemm.
129
Palmodictyon viride Kütz.
97
Pediastrum angulosum (Ehrenb.) Menegh.
20, 21
=*P. muticum* var. *crenulatum* Prescott
20
=*P. araneosum* (Racib.) G.M. Sm.
20, 21
=*P. angulosum* var. *araneosum* Racib.
5
=*P. araneosum* var. *rugulosum* (G.S. West) G.M. Sm.
20
=*P. boryanum* var. *rugulosum* G.S. West
100
Pediastrum biradiatum Meyen
20, 97, 100
Pediastrum boryanum (Turp.) Menegh.
1, 5, 6, 20, 21, 24, 25, 27, 28, 29, 82, 87, 88, 90, 92, 93, 94, 97, 98, 99, 100, 101, 105, 111, 121, 124, 125, 129
=*P. boryanum* var. *granulatum* (Kütz.) A. Br.
20, 21, 97
Pediastrum boryanum var. *brevicorne* A. Br.
=*P. muticum* Kütz.
20, 21
Pediastrum boryanum var. *longicorne* Reinsch
129
Pediastrum constrictum Hass.
101
Pediastrum duplex Meyen
1, 5, 20, 21, 24, 25, 26, 28, 29, 39, 82, 87, 88, 89, 91, 95, 97, 98, 99, 100, 105, 110, 111, 112, 116, 121, 124, 126
Pediastrum duplex var. *clathratum* (A. Br.) Lagerh.
20, 21, 97, 121
Pediastrum duplex var. *cohaerens* Bohlin
20, 21, 27, 28, 121, 124
Pediastrum duplex var. *reticulatum* Lagerh.
121
Pediastrum integrum Näg.
6, 20, 21, 124
Pediastrum obtusum Lucks
5, 20, 21
Pediastrum simplex Meyen
1, 24, 25, 26, 29, 88, 98, 99, 105, 121, 124
=*P. simplex* var. *clathratum* (Schröter) Chodat
97
=*P. simplex* var. *duodenarium* (Bail.) Rabenh.
20, 121
Pediastrum tetras (Ehrenb.) Ralfs
1, 5, 6, 20, 21, 22, 24, 25, 27, 28, 39, 88, 90, 92, 93, 94, 97, 98, 99, 100, 105, 106, 110, 111, 112, 116, 117, 121, 124, 125, 126
=*P. ehrenberghii* (Corda) A. Br.
101
Pediastrum tetras var. *tetraodon* (Corda) Rabenh.
20, 21, 27, 28, 100
Pediastrum spp.
20, 22, 23, 29, 39, 40, 82, 87, 116, 124, 126
Planctococcus alsius Skuja
76, 77
Planctococcus sp.
76
Planktosphaeria gelatinosa G.M. Sm.
23
Planktosphaeria spp.
1, 20, 22, 39, 88, 124
Protococcus viridis C. Ag.
97
Protococcus sp.
20
Quadrigula chodatii (Tan.-Ful.) G.M. Sm.
20
Quadrigula closterioides (Bohlin) Printz
20, 27, 28, 29, 98, 99, 116, 124, 125, 126

Quadrigula lacustris (Chodat) G.M. Sm.
27, 28, 100
Quadrigula pfitzeri (Schröder) G.M. Sm.
20, 21, 29, 94, 98, 99, 124
Quadrigula spp.
20, 22, 23, 29, 39, 94, 99, 106, 124, 125, 126
Radiococcus spp.
22
Rayssiella hemisphaerica Edelst. & Prescott
98, 124
Scenedesmus abundans(10)(Kirchn.) Chodat
21, 124
Scenedesmus acuminatus (Lagerh.) Chodat
1, 22, 39, 88, 98, 111
Scenedesmus acutiformis Schröder
20, 21, 90, 92, 93, 94, 124
Scenedesmus acutus Meyen
22, 121
Scenedesmus acutus f. *costulatus* (Chodat) Uherkovich
1, 88, 98
Scenedesmus arcuatus var. *capitatus* G.M. Sm.
98
Scenedesmus armatus (Chodat) Chodat
1, 88, 92, 93, 94, 98, 105
Scenedesmus asymmetricus (Schröder) Chodat
=*S. abundans* var. *asymmetricus* (Schröder) G.M. Sm .
20, 21, 27, 28
Scenedesmus bijuga (Turp.) Lagerh.
20, 21, 24, 25, 26, 27, 28, 31, 88, 90, 92, 93, 94, 100, 101, 124, 125
Scenedesmus bijuga var. *alternans* (Reinsch) Borge
20, 21, 92, 94, 97, 101
Scenedesmus brasiliensis Bohlin
5, 20, 109, 121, 124
Scenedesmus brevispina (G.M. Sm.) Chodat
=*S. longus* var. *brevispina* G.M. Sm.
20
Scenedesmus caudato-aculeolatus Chodat
=*S. thomassonii* Hortobágyi
121
Scenedesmus denticulatus Lagerh.
6, 92, 101, 121
Scenedesmus dimorphus (Turp.) Kütz.
20, 21, 24, 25, 88, 92, 97, 100
Scenedesmus dispar Bréb.
121
Scenedesmus ecornis (Ehrenb. ex Ralfs) Chodat
110, 111, 112, 121
Scenedesmus hystrix Lagerh.
22, 23
Scenedesmus incrassatulus Bohlin
20, 21, 124
Scenedesmus intermedius Chodat
111, 121
=*S. intermedius* var. *bicaudatus* Hortobágyi
111
Scenedesmus longispina Chodat
=*S. quadricauda* var. *longispina* (Chodat) G.M. Sm.
121
Scenedesmus magnus Meyen
=*S. quadricauda* var. *maximus* W. & G.S. West
20, 21
=*S. shensiensis* var. *maximus* Hortobágyi
121
Scenedesmus naegelii var. *acaudatus* Hortobágyi & Németh
121
Scenedesmus oahuensis (Lemm.) G.M. Sm.
121
Scenedesmus obliquus (Turp.) Kütz.
27, 28, 90, 92, 94, 97, 101, 121, 124
=*S. bijugatus* Kütz.
97
=*S. acuminatus* f. *costulatus* Hortobágyi
121
=*S. dactylococcoides* Chodat
121
Scenedesmus obtusus Meyen
=*S. arcuatus* (Lemm.) Lemm.
29, 90, 92, 99, 121, 124
=*S. arcuatus* var. *platydiscus* G.M. Sm.
24, 25, 88
=*S. platydiscus* (G.M. Sm.) Chodat
5
Scenedesmus opoliensis P. Richter
24, 88, 121
Scenedesmus ovalternus var. *graevenitzii* (Bernard) Chodat
98
Scenedesmus quadricauda (Turp.) Bréb.
1, 20, 21, 24, 25, 27, 28, 29, 39, 88, 90, 92, 93, 94, 97, 98, 99, 101, 105, 111, 116, 121, 124, 125, 129
=?*S. longus* Meyen
92
Scenedesmus quadricauda var. *westii* G.M. Sm.
20
Scenedesmus quadrispina Chodat
=*S. quadricauda* var. *quadrispina* (Chodat) G.M. Sm.
100
Scenedesmus regularis Svirenko
=*S. coarctatus* Hortobágyi
116, 121, 124
Scenedesmus serratus (Corda) Bohlin
99, 117, 124, 125
=*S. serratus* f. *minor* Chodat
116, 124
Scenedesmus smithii(11)Teil.
1, 88
Scenedesmus spinosus Chodat
1, 88, 121
Scenedesmus tenuispina Chodat
105

Scenedesmus spp.
1, 20, 22, 23, 29, 39, 82, 95, 99, 106, 116, 117, 121, 124, 125, 126
Schroederia setigera (Schröder) Lemm.
1, 24, 88, 118, 121, 124
Schroederia spp.
20, 124
Selenastrum spp.
20, 22, 23, 39, 121, 124, 126
Sorastrum americanum (Bohlin) Schmidle
20, 21, 94, 97, 100, 121
Sorastrum americanum var. *undulatum* G.M. Sm.
100
Sorastrum spinulosum Näg.
20, 92, 93, 94, 97, 121
Sorastrum sp.
20
Sphaerocystis schroeteri Chodat
20, 21, 27, 28, 29, 76, 77, 82, 87, 99, 118, 124, 125, 126
=*Gleococcus schroeteri* (Chodat) Lemm.
5
Sphaerocystis spp.
20, 22, 23, 76, 78, 121, 124, 125, 126
Tetradesmus smithii Prescott
20, 21
Tetradesmus wisconsinensis G.M. Sm.
90, 92
Tetraedron caudatum (Corda) Hansg.
20, 21, 27, 28, 97, 100
Tetraedron caudatum var. *incisum* (Lagerh.) Brunnth.
21
Tetraedron cruciatum (Wallich) W. & G.S. West
20
Tetraedron duospinum Ackley
124, 125
Tetraedron incus (Teil.) G.M. Sm.
=*T. regulare* var. *torsum* (Turn.) Brunnth.
97
Tetraedron lunula (Reinsch) Wille
20, 21
=*Closteridium lunulum* Reinsch
100
Tetraedron minimum (A. Br.) Hansg.
6, 27, 28, 76, 77, 92, 94, 97, 106, 118, 121, 124
=*Arthrodesmus glaucescens* Wittr.
53, 63
Tetraedron minimum f. *apiculata* Reinsch
20, 21
Tetraedron minimum f. *tetralobulatum* Reinsch
27, 28
Tetraedron regulare Kütz.
92, 94, 97, 121
=*T. tumidulum* (Reinsch) Hansg.
121
=*T. trigonum* (Näg.) Hansg.
76, 92
Tetraedron spp.
20, 22, 23, 39, 124, 126
Tetrallantos lagerheimii Teil.
20, 21
Thelesphaera spp.
121
Treubaria setigera (Archer) G.M. Sm.
118
=*T. trigonum* var. *setigerum* (Archer) Lemm.
77
Trochiscia granulata (Reinsch) Hansg.
20
Trochiscia obtusa (Reinsch) Hansg.
20
Trochiscia reticularis (Reinsch) Hansg.
97, 100, 124
Trochiscia zachariasii Lemm.
124
Trochiscia spp.
20, 99, 117, 124, 126
Westella botryoides (W. West) De Wildemann
1, 88
Westellopsis linearis (G.M. Sm.) Jao
=*Westella linearis* G.M. Sm.
118
Willea irregularis (Wille) Schmidle
=*Crucigenia irregularis* Wille
5
Zoochlorella conductrix Brandt
20
=*Chlorella conductrix* (Brandt) Beijerinck
92
Zoochlorella parasitica Brandt
21, 96, 97
Zoochlorella spp.
20, 23

Chlorosarcinales

Chlorosarcinopsis sp.
121

Cladophorales

Cladophora callicoma Kütz.
121
Cladophora fracta (Dillw.) Kütz.
97
Cladophora glomerata (L.) Kütz.
80, 97, 101, 105, 121, 123
Cladophora kuetzingianum Grun.
101
Cladophora spp.
6, 92, 95, 101, 111, 122, 124, 126
Rhizoclonium hieroglyphicum (C. Ag.) Kütz.
90, 92, 94
Rhizoclonium spp.
20, 36, 121

Coleochaetales

Chaetosphaeridium globosum (Nordst.) Klebahn
5, 20, 21, 93, 94

Chaetosphaeridium sp.
20
Coleochaete divergens Pringsh.
20, 21
Coleochaete irregularis Pringsh.
20, 94
Coleochaete nitellarum Jost
20
Coleochaete orbicularis Pringsh.
20, 21, 97, 100
Coleochaete pulvinata A. Br.
20, 21, 100
Coleochaete scutata Bréb.
5, 20, 21, 90, 92, 96, 97, 100
Coleochaete soluta (Bréb.) Pringsh.
20
Coleochaete spp.
20, 101, 121, 124, 125, 126
Dicranochaete reniformis Hieron.
6, 20, 21, 124, 125, 126
Dicranochaete sp.
20

Oedogoniales(12)

Bulbochaete alabamensis Trans. & Brown ex Tiffany
100
Bulbochaete basispora Wittr. & Lund. ex Hirn
81
Bulbochaete crenulata Pringsh. ex Hirn
81
Bulbochaete elatior Pringsh. ex Hirn
20, 21
Bulbochaete furberae var. *depressa* Taft
=*B. depressa* (Taft) Tiffany
81
Bulbochaete glabra Prescott
113
Bulbochaete intermedia De Bary ex Hirn
81, 92, 129
Bulbochaete megastoma Wittr. & Lund. ex Hirn
92
Bulbochaete minor A. Br. ex Hirn
21, 81
Bulbochaete monile var. *robusta* Hirn
=*B. robusta* (Hirn) Tiffany
81
Bulbochaete nana Wittr. ex Hirn
81
Bulbochaete rectangularis Wittr. ex Hirn
81
Bulbochaete repanda Wittr. ex Hirn
129
Bulbochaete spp.
5, 20, 29, 36, 87, 88, 92, 94, 95, 96, 97, 99, 111, 124, 125, 126
Oedogonium abbreviatum (Hirn) Tiffany
81
Oedogonium acrosporum De Bary ex Hirn
81
Oedogonium capilliforme Kütz. ex Hirn
81
Oedogonium capilliforme var. *australe* f. *de-baryanum* (Chmielevsky) Hirn
81 (*O. capilliforme* f. *de-baryanum*)
Oedogonium capitellatum Wittr. ex Hirn
81
Oedogonium cardiacum var. *carbonicum* Wittr. ex Hirn
81
Oedogonium crenulato-costatum Wittr.
81
Oedogonium crenulato-costatum var. *aureum* Tilden
=*O. aureum* (Tilden) Tiffany
81
Oedogonium crenulato-costatum var. *cylindricum* (Hirn) Tiffany
81
Oedogonium crenulato-costatum var. *longiarticulatum* Hansg. ex Hirn
=*O. longiarticulatum* (Hansg. ex Hirn) Tiffany
81
Oedogonium curtum Wittr. & Lund. ex Hirn
81
Oedogonium cyathigerum Wittr. ex Hirn
81
Oedogonium cyathigerum f. *perfectum* Hirn
=*O. perfectum* (Hirn) Tiffany
81
Oedogonium decipiens var. *dissimile* (Hirn) Tiffany
81
Oedogonium grande Kütz. ex Hirn
81
Oedogonium illinoisense Trans.
81
Oedogonium inconspicuum Hirn
81
Oedogonium longicolle Nordst. ex Hirn
81
Oedogonium longicolle var. *senegalense* Nordst. ex Hirn
=*O. senegalense* (Nordst. ex Hirn) Tiffany
81
Oedogonium macrandrium Wittr. ex Hirn
40
Oedogonium macrandrium var. *aemulans* Hirn
81
Oedogonium macrospermum W. & G.S. West
81
Oedogonium magnusii Wittr. ex Hirn
97
Oedogonium mexicanum Wittr. ex Hirn
81
Oedogonium oblongellum Kirchn. ex Hirn
81
Oedogonium obtruncatum Wittr. ex Hirn
81

Oedogonium obtruncatum var. *completum* Hirn
=*O. completum* (Hirn) Tiffany
81
Oedogonium poecilosporum Nordst. & Hirn
81
Oedogonium pringsheimii Cramer
81, 92
Oedogonium pusillum Kirchn. ex Hirn
81
Oedogonium reinschii Roy ex Cook
20
Oedogonium rothii (Le Clerc) Pringsh. ex Hirn
81
Oedogonium rugulosum f. *minutum* (Hansg.) Hirn
=*O. rugulosum* var. *minutum* (Hansg.) Tiffany
81
Oedogonium rupestre Hirn
81
Oedogonium sexangulare Cleve ex Wittr. ex Hirn
81
Oedogonium spirostriatum Tiffany
20, 21
Oedogonium spurium Hirn
81
Oedogonium tiffanii Ackley
81
Oedogonium tyrolicum Wittr. ex Hirn
97
Oedogonium wyliei Tiffany
81
Oedogonium spp.
5, 6, 20, 29, 36, 40, 87, 88, 92, 93, 94, 96, 97, 99, 100, 101, 105, 109, 110, 111, 112, 121, 124, 125, 126

Prasiolales

Schizogonium sp.
20

Siphonales

Protosiphon botryoides (Kütz.) Klebs
20, 21

Sphaeropleales

Sphaeroplea annulina (Roth) C. Ag.
97

Tetrasporales(13)

Apiocystis brauniana Näg.
6, 21, 97
Apiocystis sp.
20
Asterococcus limneticus G.M. Sm.
20 (aussi sous *Asterocystis limneticus*), 22, 23
Asterococcus superbus (Cienkowski) Scherffel
5, 100
Chlamydocapsa ampla (Kütz.) Fott
=*Gloeocystis ampla* (Kütz.) Rabenh.
100
=*Gloeocystis gigas* (Kütz.) Lagerh.
20, 21, 27, 28, 92, 94, 100, 101, 124, 129
Chlamydocapsa planctonica (W. & G.S. West) Fott
=*Gloeocystis planctonica* (W. & G.S. West) Lemm.
20, 21
Gloeochaete wittrockiana Lagerh.
21
Gloeocystis infusionum (Schrank) W. & G.S. West
97
Gloeocystis vesiculosa Näg.
20, 21, 27, 28, 92
Gloeocystis spp.
20, 22, 23, 39, 78, 106, 118, 124
Palmellopsis gelatinosa Kors.
=*Palmella mucosa* Kütz.
100
Pseudosphaerocystis sp.
=*Gemellicystis* sp.
39
Schizochlamys compacta(14) Prescott
20, 21, 77
Schizochlamys delicatula W. West
6
Schizochlamys delicatula var. *filamentosa* Brunel
6, 20
Schizochlamys gelatinosa A. Br.
6, 20, 21, 29, 99, 124
Schizochlamys spp.
20, 121
Stylosphaeridium stipitatum (Bachmann) Geitler & Gimesi
20
Stylosphaeridium sp.
20
Tetraspora gelatinosa (Vaucher) Desvaux
6, 97
Tetraspora lubrica (Roth) C. Ag.
6, 20, 21, 97, 101, 122
Tetraspora spp.
20, 36, 39, 76, 121, 124

Trentepohliales

Phycopeltis arundinacea (Mont.) De Toni
121
Trentepohlia sp.
121

Ulotrichales

Binuclearia tectorum (Kütz.) Beger ex Wichmann
5, 124
=*B. tatrana* Wittr.
20, 21, 124, 126
Binuclearia spp.
112, 121, 124
Caespitella pascheri Vischer
121
Cylindrocapsa conferta W. West
42, 97
Cylindrocapsa geminella var. *minor* Hansg.
20, 21

Cylindrocapsa sp.
20
Geminella ellipsoidea (Prescott) G.M. Sm.
=*Hormidiopsis ellipsoidea* Prescott
20, 21
Geminella interrupta (Turp.) Lagerh.
97
Geminella minor (Näg.) Heering
121
Geminella mutabilis (Bréb.) Wille
121
Geminella spp.
20, 118
Gloeotila sp.
39
Hormidiopsis sp.
20
Koliella longiseta (Vischer) Hindák
121, 124
Microspora amoena (Kütz.) Rabenh.
6
Microspora crassior (Hansg.) Haz.
101
Microspora pachyderma (Wille) Lagerh.
5
Microspora quadrata Haz.
121
Microspora stagnorum (Kütz.) Lagerh.
6, 40, 94, 100, 129
Microspora tumidula Haz.
20, 121
Microspora willeana Lagerh.
96, 121, 129
Microspora spp.
20, 22, 23, 29, 36, 99, 124
Planctonema lauterbornii Schmidle
5, 23
Planctonema sp.
39
Radiofilum conjunctivum Schmidle
20
Radiofilum transversale (Bréb.) Ramanathan
=*R. irregulare* (Wille) Brunnth.
20
Stichococcus scopulinus Haz.
96
Stichococcus sp.
37
Ulothrix aequalis Kütz.
101, 107, 121
Ulothrix cylindrica Prescott
121
Ulothrix moniliformis Kütz.
20
Ulothrix subconstricta G.S. West
121
Ulothrix subtilissima Rabenh.
31, 121
Ulothrix tenerrima Kütz.
20, 92, 94, 96, 101, 121
Ulothrix tenuissima Kütz.
121
Ulothrix variabilis Kütz.
96, 101, 121
Ulothrix zonata (Weber & Mohr) Kütz.
6, 92, 94, 96, 97, 121
Ulothrix spp.
20, 29, 93, 95, 99, 105, 109, 110, 111, 112, 124

Ulvales

Prasiola crispa (Lightf.) Menegh.
6
Schizomeris sp.
121

Volvocales

Carteria abiscoensis Skuja
21, 114
Carteria spp.
76, 121
Chlamydomonas caudata Wille
124
Chlamydomonas dinobryonis G.M. Sm.
24, 25, 88
Chlamydomonas epiphytica G.M. Sm.
76
Chlamydomonas globosa Snow
20, 97, 118
Chlamydomonas gloeopara Rodhe & Skuja
76, 77, 118
Chlamydomonas nivalis (Bauer) Wille
=*Sphaerella nivalis* (Bauer) Sommerf.
120, 129
Chlamydomonas pseudopertusa Ettl
114
Chlamydomonas spp.
6, 20, 21, 23, 27, 28, 76, 77, 101, 114, 118, 121, 124
Chlorogonium elongatum (Dang.) Dang.
21, 114, 124
Chlorogonium euchlorum Ehrenb.
20
Chlorogonium maximum Skuja
39, 124
Chlorogonium sp.
124
Eudorina elegans Ehrenb.
1, 5, 20, 21, 24, 25, 88, 97, 98, 101, 111, 114, 121
Eudorina spp.
20, 22, 23, 39, 87, 110, 112, 124
Gloeomonas sp.
21
Gonium formosum Pascher
21, 114, 124
Gonium pectorale O.F. Müll.
6, 20, 97, 124
Gonium sociale (Dujardin) Warming
=?*G. lacustre* G.S. West
97

Gyromitus cordiformis Skuja
118
Haematococcus pluvialis Flotow
=*Sphaerella lacustris* (Girod.) Wittr.
12, 97
Pandorina minodii Chodat
88
Pandorina morum (O.F. Müll.) Bory
1, 4, 6, 20, 21, 24, 25, 29, 31, 76, 82, 87, 88, 92, 93, 94, 97, 98, 99, 101, 114, 121, 124, 126
Pandorina spp.
76, 95
Pleodorina californica Shaw
24, 25, 88, 94
Pleodorina illinoisensis Kofoid
97
Scourfieldia complanata G.S. West
27, 28
Scourfieldia sp.
76
Volvox aureus Ehrenb.
20, 21, 24, 25, 87, 88, 97, 100
Volvox globator L.
24, 25, 88
Volvox tertius Meyer
121
Volvox spp.
39, 121, 124

Zygnematales
Desmidiaceae

Actinotaenium clevei (Lund.) Teil.
20
=*Cosmarium clevei* (Lund.) Lütk.
21, 46, 53, 56, 60, 64, 66
Actinotaenium colpopelta (Bréb. ex Archer) Compère
=*Cosmarium viride* (Corda) ex Joshua
43, 46, 50, 54, 60, 64, 66
Actinotaenium colpopelta f. *minus* (W. West) Compère
=*Cosmarium viride* f. *minor* W. West
43, 64, 96
Actinotaenium crassiusculum (De Bary) Teil.
=*Penium crassiusculum* De Bary
60
Actinotaenium cucurbita (Bréb. ex Ralfs) Teil. ex Růžička & Pouzar
5, 20
=*Cosmarium cucurbita* Bréb. ex Ralfs
43, 46, 50, 56, 60, 64, 66, 74, 92 (*Euastrum cucurbita*), 93, 100, 129
Actinotaenium cucurbita var. *attenuatum* (G.S. West) Teil.
=*Cosmarium cucurbita* var. *attenuatum* G.S. West
60, 66
Actinotaenium cucurbitinum (Biss.) Teil.
=*Cosmarium cucurbitinum* (Biss.) Lütk.
40, 43, 56, 60, 66, 100
Actinotaenium curtum (Bréb. ex Ralfs) Teil. ex Růžička & Pouzar
=*Penium curtum* Bréb. ex Ralfs
4, 97
Actinotaenium curtum var. *attenuatum* (Bréb. ex Ralfs) Teil. ex Růžička & Pouzar
=*Cosmarium attenuatum* Bréb. ex Ralfs
43, 66
Actinotaenium diplosporum (Lund.) Teil.
=*Cosmarium diplosporum* (Lund.) Lütk.
66, 73
=*Cosmarium diplosporum* var. *intermedia* Ir.-Mar.
73
=*Cosmarium diplosporum* var. *major* W. West
53
Actinotaenium diplosporum var. *americanum* (W. & G.S. West) Teil.
20
=*Cylindrocystis americana* W. & G.S. West
42, 47, 52, 60, 63, 74
Actinotaenium diplosporum var. *americanum* f. *minus* (Cushman) Teil.
=*Cylindrocystis americana* var. *minor* Cushman
43, 47, 52, 60, 63, 73, 74, 100
Actinotaenium elongatum (Racib.) Teil.
=*Cosmarium elongatum* Racib.
46, 60, 66, 74
Actinotaenium globosum (Bulnh.) Förster
=*Cosmarium globosum* Bulnh.
43, 50, 56, 66, 94
Actinotaenium globosum f. *minus* (Boldt) Förster ex Compère
=*Cosmarium globosum* var. *minus* Hansg.
46, 60, 66
Actinotaenium inconspicuum (W. & G.S. West) Teil.
=*Penium inconspicuum* W. & G.S. West
27, 28
Actinotaenium rufescens (Cleve) Teil.
20
=*Penium rufescens* Cleve
43, 60, 62
Actinotaenium subglobosum (Nordst.) Teil.
5, 20, 21
Actinotaenium wollei (W. & G.S. West) Teil. ex Růžička & Pouzar
=*Cosmarium wollei* (W. & G.S. West) Grönbl.
60, 64, 74
Actinotaenium sp.
20
?*Arthrodesmus notochondrus* Lagerh.
47
Bambusina borreri (Ralfs) Cleve
5, 21, 100, 110, 112, 124, 125, 126
=*B. brebissonii* Kütz. ex Kütz.
20
=*B. borreri* var. *gracilescens* Nordst.
21

=*B.* (*Gymnozyga*) *moniliformis* Ehrenb., nom. illeg.
52, 54, 59, 60, 76, 77
=*B.* (*Gymnozyga*) *moniliformis* f. *maxima* Ir.-Mar., nom. illeg.
60
=*B.* (*Gymnozyga*) *moniliformis* var. *gracilescens* Nordst., nom. illeg.
60
=*Gymnozyga moniliformis* Ehrenb.
6, 29, 43, 47, 63, 73, 74, 87, 92, 93, 97, 98, 99, 109, 117, 124
=*Gymnozyga moniliformis* f. *maxima* Ir.-Mar.
43, 63, 73, 74, 124
=*Gymnozyga moniliformis* f. *minor* Ir.-Mar.
74
=*Gymnozyga moniliformis* var. *gracilescens* Nordst.
29, 43, 47, 63, 74, 99, 124
Bambusina spp.
20, 124
=*Gymnozyga* spp.
23, 39
Closterium abruptum W. West
20, 21, 43, 45, 57, 60, 61, 64, 70, 73, 74, 75, 129
Closterium abruptum f. *angustissima* Schmidle
74
Closterium abruptum var. *majus* Huber-Pestalozzi
75
Closterium acerosum (Schrank) Ehrenb. ex Ralfs
1, 4, 24, 25, 43, 44, 45, 48, 60, 61, 64, 70, 73, 74, 75, 88, 92, 93, 96, 97, 111, 121
Closterium acerosum var. *elongatum* Bréb.
24, 25, 43, 57, 60, 61, 88
Closterium acerosum var. *minus* Hantzsch
70, 73, 92
Closterium acerosum var. *tumidum* Borge
70, 74
Closterium aciculare T. West
1, 29, 39, 70, 88, 99, 105, 124
Closterium aciculare var. *subpronum* W. & G.S. West
24, 25, 88, 97
Closterium acutum (Lyngb.) Bréb. ex Ralfs
1, 20, 21, 43, 44, 48, 57, 60, 61, 64, 73, 75, 121
Closterium acutum var. *tenuius* Nordst.
64
Closterium acutum var. *variabile* (Lemm.) Krieger
75
Closterium angustatum Kütz. ex Ralfs
5, 20, 21, 29, 43, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 87, 99, 124
Closterium angustatum var. *asperum* W. West
=*C. angustatum* var. *angustatum* W. West sensu Ir.-Mar.
60, 61, 74
Closterium angustatum var. *clavatum* Hastings
20, 43, 45, 53, 60, 61, 64, 70, 73, 74, 100
Closterium angustatum var. *recta* Ir.-Mar.
60, 73
Closterium archerianum Cleve
20, 21, 43, 60, 61, 64, 70, 74, 92, 124
Closterium archerianum f. *compressum* Klebs
43
Closterium archerianum f. *grande* Prescott
=*C. archerianum* f. *majus* Ir.-Mar.
61, 64
Closterium attenuatum Ehrenb. ex Ralfs
92
Closterium baillyanum Bréb.
5, 20, 21, 45, 48, 60, 61, 64, 70, 74, 96
Closterium baillyanum f. *asperulatum* (W. & G.S. West) Ir.-Mar.
61, 64
=*C. baillyanum* f. *stellatum* Grönbl.
48
Closterium baillyanum f. *crassum* Ir.-Mar.
75
Closterium baillyanum var. *parvulum* Grönbl.
48, 60, 61
=*C. baillyanum* var. *parvulum* f. *sigmoideum*(15) Ir.-Mar.
61
Closterium calosporum var. *brasiliense* Börg.
20, 21
Closterium closterioides (Ralfs) Louis & Peeters
=*C. libellula* Focke
5, 20, 21, 43, 45, 48, 53, 57, 60, 61, 64, 70, 74, 75, 92, 94, 96, 100
=*C. libellula* f. *sigmoideum*(15) Ir.-Mar.
64
Closterium closterioides var. *intermedium* (Roy & Biss.) Růžička
=*C. libellula* var. *intermedium* (Roy & Biss.) G.S. West
5, 20, 33, 43, 45, 48, 57, 60, 61, 64, 70, 74, 92
=*C. libellula* var. *interruptum* (W. & G.S. West) Donat
20, 21, 45, 48, 57, 60, 61
=*C. libellula* var. *punctatum* (Racib.) Krieger
64
=*C. libellula* f. *minus* (Heimerl) Beck-Mannagetta
61, 64, 70
Closterium cornu Ehrenb. ex Ralfs
57, 60, 61, 64, 70, 75, 97
Closterium cornu var. *minus* Ir.-Mar.
60
Closterium costatum Corda ex Ralfs
20, 21, 29, 33, 43, 45, 48, 57, 60, 61, 70, 73, 74, 92, 93, 99, 124
Closterium costatum f. *rectum* Prescott
=*C. costatum* forma W. & G.S. West
61
Closterium costatum var. *dilatatum* (W. & G.S. West) Krieger
=*C. dilatatum* W. & G.S. West
61

Closterium costatum var. *subcostatum* (Nordst.) Krieger
20, 21, 70
=*C. subcostatum* Nordst.
64
Closterium costatum var. *westii* Cushman
20, 21, 43, 57, 75
Closterium cynthia De Notaris
20, 21, 43, 48, 57, 60, 61, 64, 74, 75, 92, 124
Closterium dianae Ehrenb. ex Ralfs
5, 20, 21, 43, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 90, 92, 93, 97, 117, 124, 125
Closterium dianae var. *arcuatum* (Bréb.) Rabenh.
20, 21, 43, 48, 57, 60, 61, 70, 73, 74, 75, 92, 94, 100, 124
Closterium didymotocum (Corda) Ralfs
20, 21, 43, 45, 48, 53, 57, 60, 61, 64, 70, 74, 75, 92
=*C. didymotocum* f. *sigmoideum*(15) Ir.-Mar.
60
=*C. baillyanum* f. *sigmoideum*(15) Ir.-Mar.
48, 61, 64
Closterium didymotocum var. *crassum* Grönbl.
60, 61, 64, 70, 74
Closterium didymotocum var. *glabrum* Borge (=O.F. Andersson)
20
Closterium didymotocum var. *maximum* Grönbl.
61, 70
Closterium eboracense (Ehrenb.) Turn.
60, 61, 64, 70, 73, 75
Closterium ehrenbergii Menegh. ex Ralfs
20, 21, 43, 44, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 92, 93, 94, 97, 100, 111, 121
=*C. ehrenbergii* f. *sigmoideum*(15) Ir.-Mar.
43, 61, 64
Closterium ehrenbergii f. *magnum* Prescott
=*C. ehrenbergii* f. *majus* Ir.-Mar.
64, 73
Closterium ehrenbergii var. *malinvernianum* (De Notaris) Rabenh.
=*C. malinvernianum* De Notaris
64, 93, 94
=*C. malinvernianum* f. *sigmoideum*(15) Ir.-Mar.
64
Closterium ehrenbergii var. *percrassum* (Borge) Grönbl.
=*C. ehrenbergii* var. *immane* Wolle
75
Closterium gracile Bréb. ex Ralfs
5, 20, 21, 29, 43, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 87, 93, 97, 99, 121, 124, 125, 126
=*C. gracile* f. *sigmoideum*(15) Ir.-Mar.
64
Closterium gracile var. *elongatum* W. & G.S. West
33, 43, 45, 48, 53, 57, 60, 61, 64, 70, 92
Closterium gracile var. *intermedium* Ir.-Mar.
43, 45, 48, 57, 60, 61, 64, 70, 73, 74, 75
Closterium gracile var. *tenue* (Lemm.) W. & G.S. West
20, 29, 43, 57, 61, 64, 70, 74, 75, 99, 124
Closterium idiosporum W. & G.S. West
29, 43, 57, 60, 61, 64, 70, 74, 75, 99, 124
Closterium incurvum Bréb.
43, 44, 45, 48, 60, 61, 64, 70, 73, 74, 75, 121, 124
=*C. venus* var. *incurvum* (Bréb.) Krieger
57
Closterium incurvum f. *latius* Ir.-Mar.
60, 61, 64, 75
Closterium intermedium Ralfs
5, 43, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 92, 93, 96, 97, 100, 109
Closterium jenneri Ralfs
20, 21, 43, 45, 60, 61, 64, 70, 73, 74, 97, 101, 129
=*C. jenneri* forma Ir.-Mar.
60
Closterium jenneri var. *robustum* G.S. West
43, 48, 57, 60, 61, 70, 74, 75, 100
Closterium juncidum Ralfs
20, 21, 27, 28, 29, 43, 45, 53, 57, 60, 61, 64, 70, 74, 75, 99, 124
Closterium juncidum var. *brevius* (Ralfs) Roy
61
Closterium juncidum var. *elongatum* Roy & Biss.
60, 61, 64
Closterium juncidum var. *elongatum* f. *rectum* Ir.-Mar.
70
Closterium kuetzingii Bréb.
20, 21, 27, 28, 29, 43, 44, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 88, 92, 94, 96, 98, 99, 124, 125, 126
=*C. kuetzingii* f. *sigmoideum*(15) Ir.-Mar.
29, 33, 43, 45, 48, 57, 60, 61, 64, 70, 74, 99, 124
Closterium lanceolatum Kütz. ex Ralfs
20, 21, 43, 45, 48, 57, 60, 61, 64, 70, 73, 74, 75, 121, 124
=*C. lanceolatum* f. *sigmoideum*(15) Ir.-Mar.
73
Closterium lanceolatum var. *parvum* W. & G.S. West
70
Closterium laterale var. *simplicius* Hughes
61
Closterium leibleinii Kütz. ex Ralfs
1, 20, 21, 27, 28, 29, 40, 43, 44, 45, 53, 57, 60, 61, 64, 70, 73, 74, 75, 88, 92, 99, 100, 111, 121, 124, 125
Closterium lineatum Ehrenb. ex Ralfs
20, 21, 43, 45, 48, 53, 57, 60, 61, 70, 73, 74, 75, 87, 92, 97, 100
=*C. lineatum* f. *sigmoideum*(15) Ir.-Mar.
61
Closterium lineatum f. *laeve* Ir.-Mar.
61

Closterium lineatum var. *costatum* Wolle
43, 45, 48, 57, 60, 61, 74, 75, 124
Closterium lineatum var. *elongatum* Rosa
70
Closterium littorale Gay
43, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 96
=*C. siliqua* W. & G.S. West
43, 53, 57, 61, 64, 75
Closterium lunula (O.F. Müll.) Nitzsch ex Ralfs
1, 20, 21, 43, 45, 48, 57, 60, 61, 64, 70, 73, 74, 75, 82, 87, 88, 92, 93, 94, 97, 100
Closterium lunula f. *biconvexum* (Schmidle) Kossinsk.
=*C. lunula* var. *biconvexum* Schmidle
43, 48, 57, 60, 61, 64, 70, 74, 98
Closterium lunula f. *minus* W. & G.S. West
57, 92
Closterium lunula var. *carinthiacum* Beck-Mannagetta
61
Closterium lunula var. *coloratum* Klebs
60, 61, 64, 70, 73, 75
Closterium lunula var. *intermedium* Gutw.
20, 21, 60, 61, 64, 70, 73, 74
Closterium lunula var. *massartii* (De Wildemann) Krieger
70
Closterium lunula var. *maximum* Borge
43, 45, 48, 60, 61, 64, 70, 73, 74, 75
Closterium macilentum Bréb.
33, 43, 45, 48, 57, 60, 61, 64, 70, 74, 92
Closterium macilentum var. *coloratum* Elenkin & Lobik
61
=*C. macilentum* var. *coloratum* f. *sigmoideum*(15) Ir.-Mar.
61
Closterium macilentum var. *minus* W. & G.S. West
70
Closterium malinvernianiforme Grönbl.
70
Closterium malmei Borge
45, 61, 74, 75, 100
Closterium malmei var. *semicirculare* Borge
74, 75
Closterium moniliferum (Bory) Ehrenb. ex Ralfs
1, 20, 24, 25, 43, 44, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 87, 88, 92, 93, 94 (*C. moniliforme*), 96, 97, 111, 121, 124, 125, 126
Closterium nasutum Nordst.
60, 61, 64, 75
Closterium navicula (Bréb.) Lütk.
5, 20, 21, 48, 61, 74, 92, 97, 124
=*Penium navicula* Bréb.
28
Closterium nematodes var. *proboscideum* Turn.
60, 61, 64, 75
Closterium nematodes var. *proboscideum* f. *majus* Ir.-Mar.
5, 61
Closterium parvulum Näg.
1, 20, 21, 29, 42, 43, 44, 45, 57, 60, 61, 64, 70, 73, 74, 75, 88, 92, 93, 96, 99, 121, 124, 129
=*C. parvulum* f. *sigmoideum*(15) Ir.-Mar.
20, 21, 43, 124
Closterium parvulum var. *angustum* W. & G.S. West
43, 61, 64, 70, 73, 74, 75, 76, 94, 97
Closterium parvulum var. *maius* W. West
74
Closterium peracerosum Gay
70
Closterium planum Hughes
74
Closterium porrectum Nordst.
70, 74
Closterium porrectum var. *angustatum* W. & G.S. West
20, 21
Closterium praelongum Bréb.
29, 43, 44, 45, 48, 57, 60, 61, 64, 70, 74, 75, 87, 99, 124
Closterium praelongum var. *brevius* (Nordst.) Krieger
92
=?*C. praelongum* f. *brevius* W. West [=f. *brevior* W. & G.S. West sensu Ir.-Mar.]
43, 70, 74
Closterium pritchardianum Archer
24, 25, 43, 44, 45, 48, 57, 60, 61, 64, 70, 73, 74, 88
Closterium pritchardianum f. *attenuatum* Ir.-Mar.
61
Closterium pronum Bréb.
43, 48, 53, 57, 61, 64, 73, 74, 75, 121
Closterium pseudodianae Roy
20, 21, 24, 25, 43, 45, 57, 60, 61, 64, 70, 73, 74, 75, 88, 92, 121, 124, 125, 126
Closterium pseudolunula Borge
20, 21, 74, 75
Closterium pseudolunula var. *majus* Ir.-Mar.
61, 73
Closterium ralfsii Bréb. ex Ralfs
5, 43, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 87, 92
=*C. ralfsii* var. *immane* Cushman
33, 43, 48, 61, 74, 92
=*C. ralfsii* var. *immane* f. *sigmoideum*(15) Ir.-Mar.
61
Closterium ralfsii var. *hybridum* Rabenh.
29, 43, 44, 45, 48, 57, 60, 61, 64, 70, 73, 74, 75, 92, 93, 97, 99, 100, 110, 112, 124
=*C. decorum* Bréb.
44, 57
=*C. ralfsii* var. *hybridum* f. *sigmoideum*(15) Ir.-Mar.
43, 45, 48, 60, 74, 75
Closterium ralfsii var. *hybridum* f. *laeve* Ir.-Mar.
61
Closterium ralfsii var. *hybridum* f. *procera* Ir.-Mar.
75

Closterium ralfsii var. *hybridum* forma Ir.-Mar.
43
Closterium regulare Bréb.
33, 43, 48, 57, 60, 61, 64, 70, 74, 100
Closterium rostratum Ehrenb. ex Ralfs
20, 43, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 92, 97, 124
=*C. rostratum* var. *brevirostratum* W. West
43, 60, 75
=*C. rostratum* f. *sigmoideum*(15) Ir.-Mar.
43, 121
Closterium rostratum var. *subrostratum* Krieger
75
Closterium setaceum Ehrenb. ex Ralfs
20, 21, 27, 28, 29, 43, 44, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 82, 87, 97, 99, 109, 110, 112, 124, 125, 126
=*C. setaceum* f. *sigmoideum*(15) Ir.-Mar.
43, 64, 75
Closterium setaceum f. *rectum* Ir.-Mar.
70, 74
Closterium spetsbergense var. *laticeps* Grönbl.
60, 61, 64
=*C. spetsbergense* var. *laticeps* f. *sigmoideum*(15) Ir.-Mar.
61
Closterium strigosum Bréb.
43, 60, 64, 70, 73, 75
Closterium striolatum Ehrenb. ex Ralfs
4, 43, 44, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 92, 93, 97, 100, 129
=*C. didymotocum* var. *striatum* Lowe
45
=*C. striolatum* f. *sigmoideum*(15) Ir.-Mar.
43, 48, 61, 64, 74, 100
=*C. truncatum* Turn.
64
Closterium striolatum f. *rectum* W. West
43, 53, 57, 60, 61, 64, 70
Closterium striolatum var. *borgei* (Borge) Krieger
70
Closterium striolatum var. *erectum* Klebs
43, 45, 48, 53, 60, 61, 64, 70, 74, 75
Closterium striolatum var. *spirostriolatum* Ir.-Mar.
61
=*C. striolatum* var. *spirostriolatum* f. *sigmoideum*(15) Ir.-Mar.
61
Closterium striolatum var. *subtruncatum* (W. & G.S. West) Krieger
57, 61
=*C. subtruncatum* W. & G.S. West
6, 43, 45, 48, 60, 64, 70, 74, 75, 100
Closterium subjuncidiforme Grönbl.
75
Closterium subscoticum Gutw.
74
Closterium subulatum (Kütz.) Bréb.
43, 64, 70, 75, 92, 93, 121, 124, 126
Closterium subulatum var. *maius* Krieger
70
Closterium toxon W. West
20, 21, 29, 33, 43, 45, 57, 60, 61, 64, 70, 74, 92, 99, 124
=*C. toxon* f. *sigmoideum*(15) Ir.-Mar.
60
Closterium tumidum Johnson
33, 43, 45, 48, 57, 60, 61, 64, 73, 74, 96
Closterium tumidum f. *irenee-mariae* Prescott
=*C. tumidum* f. *majus* Ir.-Mar.
75
Closterium tumidum var. *nylandicum* Grönbl.
20, 21
Closterium turgidum Ehrenb. ex Ralfs
4, 43, 45, 48, 57, 60, 61, 64, 70, 73, 74, 75, 93, 94, 100
=*C. turgidum* f. *sigmoideum*(15) Ir.-Mar.
61
Closterium turgidum var. *borgei* (Borge) Defl.
64
Closterium turgidum var. *giganteum* Nordst.
61
=*C. subturgidum* Nordst.
61, 64, 74
=*C. subturgidum* var. *giganteum* Nordst.
60, 61, 64, 70, 74, 75
Closterium ulna Focke
20, 21, 43, 61, 64, 70, 74, 75
Closterium ulna var. *recurvatum* (Roll) Krieger
64
Closterium venus Kütz. ex Ralfs
20, 21, 40, 43, 45, 48, 53, 57, 60, 61, 64, 70, 73, 74, 75, 90, 92, 93, 94, 97, 121
=*C. venus* f. *sigmoideum*(15) Ir.-Mar.
48, 61, 74
Closterium venus f. *latum* Ir.-Mar.
64
Closterium venus f. *minus* Roll
=*C. venus* f. *minus* Ir.-Mar.
64
Closterium spp.
1, 20, 22, 23, 29, 32, 37, 82, 87, 92, 99, 109, 116, 117, 121, 124, 125, 126
Cosmarium abbreviatum Racib.
60, 66, 74, 92, 93, 94
Cosmarium abbreviatum f. *pygmaeum* Messik.
21
Cosmarium abbreviatum var. *germanicum* (Racib.) Krieger & Gerloff
20
Cosmarium abbreviatum var. *minus* (W. & G.S. West) Krieger & Gerloff
=*C. abbreviatum* f. *minus* W. & G.S. West
66, 92
Cosmarium abruptum var. *granulatum* W. & G.S. West
66

Cosmarium alatum var. *aequatoriense* Nordst.
43, 46, 50, 66
Cosmarium alpestre Roy & Biss.
66
Cosmarium alpestre var. *minus* Ir.-Mar.
64, 66
Cosmarium amoenum (Bréb.) Ralfs
5, 20, 21, 43, 46, 50, 56, 60, 64, 66, 74, 92 (*Euastrum amoenum*), 124, 125
Cosmarium amoenum var. *compactum* W. & G.S. West
43
Cosmarium amoenum var. *mediolaeve* Nordst.
20, 21, 43, 60, 66, 74
Cosmarium anceps Lund.
50, 66, 92, 129
=*C. parvulum* Bréb.
92
Cosmarium angulare Johnson
29, 43, 46, 50, 56, 64, 66, 73, 74, 92, 99, 100, 121, 124
Cosmarium angulare var. *canadense* Ir.-Mar.
43, 60, 64, 66, 73, 74, 94
Cosmarium angulosum Bréb.
1, 20, 21, 43, 50, 53, 56, 60, 64, 66, 73, 88, 92, 93, 94, 100, 105, 121
Cosmarium angulosum f. *rotundatum* Ir.-Mar.
64, 66
Cosmarium angulosum var. *concinnum* (Rabenh.) W. & G.S. West
20, 56, 66, 77 (var. *conicum*)
Cosmarium anisochondrum Nordst.
94
Cosmarium annulatum (Näg.) De Bary
53, 92
Cosmarium apertum Turn.
60, 74
Cosmarium arctoum Nordst.
56, 129
Cosmarium arctoum f. *minus* W. West
50, 53, 66
Cosmarium asphaerosporum Nordst.
56, 60, 66
Cosmarium baileyi Wolle
46, 60, 66
Cosmarium balteum W. & G.S. West
50, 56, 66
Cosmarium binum Nordst.
20, 21, 66, 97
Cosmarium bioculatum Bréb. ex Ralfs
20, 21, 27, 28, 29, 46, 50, 53, 56, 60, 66, 73, 74, 92, 93, 94, 99, 100, 121, 124, 129
=*C. bioculatum* f. *majus* Ir.-Mar.
66
=*C. bioculatum* var. *punctatum* Ir.-Mar.
60
Cosmarium bioculatum f. *reniforme*[16] Brunel
20
Cosmarium bioculatum var. *hians* W. & G.S. West
27, 28, 46, 60, 64
Cosmarium bipunctatum Börg.
20, 21, 27, 28, 29, 43, 46, 53, 56, 60, 64, 73, 99, 117, 121, 124
Cosmarium biretum (Bréb.) Ralfs
129
Cosmarium biretum var. *minus* Hansg.
20, 60
Cosmarium biretum var. *trigibberum* Nordst.
46, 60
Cosmarium blyttii Wille
20, 21, 43, 46, 56, 60, 64, 66, 73, 74, 94, 100
Cosmarium boeckii Wille
20, 21, 43, 46, 50, 53, 56, 60, 64, 66, 73, 74, 92, 94, 100
Cosmarium botrytis (Menegh.) Ralfs
4, 20, 40, 43, 46, 50, 53, 56, 60, 64, 66, 73, 87, 92, 93, 94, 97, 101, 129
Cosmarium botrytis var. *canadense* Ir.-Mar.
64
Cosmarium botrytis var. *depressum* W. & G.S. West
66
Cosmarium botrytis var. *mediolaeve* W. West
46, 60, 66, 92
Cosmarium botrytis var. *subtumidum* Wittr.
1, 40, 46, 50, 56, 60, 64, 66, 88
Cosmarium botrytis var. *subtumidum* f. *irenee-mariae* Wade
=*C. botrytis* var. *subtumidum* forma Ir.-Mar.
43, 64, 73
Cosmarium botrytis var. *tumidum* Wolle
94, 97
Cosmarium broomei (Thwaites) Ralfs
46, 56, 60, 64
Cosmarium caelatum Ralfs
46, 53, 60, 64, 90, 92
Cosmarium caelatum var. *truncatum* Taylor
46, 60, 64
Cosmarium calcareum Wittr.
66
Cosmarium canadense Ir.-Mar.
43, 46, 53, 56, 60, 64, 66, 73
Cosmarium capense (Nordst.) De Toni
64
Cosmarium capitulum Roy & Biss.
53
?*Cosmarium circulare* f. *minus* W. & G.S. West
46, 50, 53, 60, 66, 92
?*Cosmarium circulare* var. *depressum* Ir.-Mar.
50, 64, 66, 74
Cosmarium clepsydra var. *mauricianum* Ir.-Mar.
50, 66
Cosmarium commissurale var. *crassum* Nordst.
20, 21, 43, 46, 50, 56, 60, 64, 66, 73, 74, 100
Cosmarium connatum (Bréb.) Ralfs
20, 21, 26, 43, 46, 50, 53, 56, 60, 64, 66, 74, 97, 100

Cosmarium connatum var. *depressum* Ir.-Mar.
66
Cosmarium conspersum Ralfs
50, 66, 92, 94
Cosmarium conspersum f. *minus* Borge
129
Cosmarium conspersum var. *latum* (Bréb.) W. & G.S. West
92
Cosmarium conspersum var. *subrotundatum* W. West
92
Cosmarium contractum Kirchn.
20, 21, 29, 43, 46, 50, 53, 56, 60, 64, 66, 73, 74, 92, 94, 97, 99, 100, 124
=*C. contractum* var. *jacobsenii* (Roy) W. & G.S. West
66
Cosmarium contractum var. *ellipsoideum* (Elfv.) W. & G.S. West
5, 20, 21, 24, 25, 43, 46, 50, 56, 60, 64, 66, 73, 74, 88, 94, 100
Cosmarium contractum var. *minutum* (Delp.) W. & G.S. West
=*C. contractum* var. *ellipsoideum* forma W. & G.S. West
56
=*C. contractum* var. *ellipsoideum* f. *minus* Borge in Ir.-Mar.
66, 74
Cosmarium contractum var. *rectangulare* Ir.-Mar.
66
Cosmarium cosmetum W. & G.S. West
46, 60, 64, 66
Cosmarium costatum Nordst.
64, 93, 129
Cosmarium crenatum Ralfs
20, 21, 46, 60, 64, 73, 74, 124, 125, 126, 129
Cosmarium cucumis Corda ex Ralfs
43, 46, 50, 53, 60, 64, 66, 74, 129
Cosmarium cucumis var. *helveticum* Nordst.
20
Cosmarium cucumis var. *magnum* Racib.
=*C. cucumis* f. *majus* W. West in Ir.-Mar.
60
Cosmarium cyclicum Lund.
46, 60, 96
Cosmarium cyclicum var. *arcticum* Nordst.
66
Cosmarium cyclicum var. *nordstedtianum* (Reinsch) W. & G.S. West
66, 96, 129
Cosmarium cymatopleurum Nordst.
50, 66, 92
Cosmarium debaryi Archer
64, 129
Cosmarium dentatum Wolle
46, 50, 56, 60, 64, 66, 73, 92, 94, 97
Cosmarium dentatum var. *glabrum* Ir.-Mar.
56
Cosmarium denticulatum Borge
20, 21, 64, 100
Cosmarium denticulatum f. *borgei* Ir.-Mar.
1, 20, 21, 43, 44, 46, 50, 56, 60, 64, 66, 88, 100
Cosmarium denticulatum f. *victorinii* Ir.-Mar.
43, 44, 46, 60, 64, 66, 100
Cosmarium denticulatum var. *ovale* Grönbl.
5
Cosmarium depressum (Näg.) Lund.
24, 25, 43, 46, 50, 53, 60, 64, 66, 73, 88, 92, 93, 94, 97, 121
Cosmarium depressum f. *minutum*(17) Heimerl
=*C. subdepressum* W. & G.S. West
21
Cosmarium depressum var. *achondrum* (Boldt) W. & G.S. West
97
=*C. depressum* var. *elevatum* Borge
20, 21
Cosmarium depressum var. *reniforme* W. & G.S. West
53, 94
Cosmarium difficile Lütk.
20, 21, 43, 46, 50, 53, 56, 60, 64, 66, 74, 92, 100
Cosmarium difficile var. *dilatatum* Borge
5, 43, 46, 50, 53, 60, 66
Cosmarium elegantissimum forma Ir.-Mar.
43
Cosmarium eloiseanum Wolle
20, 21, 64
Cosmarium eloiseanum var. *depressum* W. & G.S. West
43, 46, 56, 60, 64, 66, 100
Cosmarium excavatum var. *duplo-maius* (Wille) Förster
100
Cosmarium exiguum Archer
20, 21, 56, 64, 66
Cosmarium exiguum var. *subrectangulum* W. & G.S. West
56, 66
Cosmarium flavum Roy & Biss.
66
Cosmarium fontarabiense Croasdale
=*C. subdeplanatum* Schmidle
43, 50, 60, 64, 66
Cosmarium fontarabiense f. *maius* Croasdale
=*C. subdeplanatum* f. *majus* Ir.-Mar.
74
Cosmarium formosulum Hoff
46, 56, 60, 66, 92
Cosmarium formosulum var. *nathorstii* (Boldt) W. & G.S. West
43, 46, 53, 56, 60, 73, 92
Cosmarium furcatospermum W. & G.S. West
29, 43, 46, 50, 53, 56, 60, 64, 66, 73, 74, 92, 99, 100, 124

Cosmarium galeritum Nordst.
43, 50, 56, 64, 66, 74, 94, 100
Cosmarium galeritum var. *subtumidum* Borge
50, 66
Cosmarium gayanum var. *eboracense* W. & G.S. West
43, 60, 64, 66
Cosmarium geminatum Lund.
43, 46, 60, 121
Cosmarium granatum Bréb. ex Ralfs
20, 21, 40, 43, 46, 50, 53, 56, 60, 64, 66, 73, 74, 90, 92, 93, 94, 97, 121, 129
Cosmarium granatum var. *ocellatum* W. & G.S. West
66, 94
Cosmarium hammeri Reinsch
20, 43, 50, 60, 64, 66, 97, 100
Cosmarium hammeri var. *homalodermum* (Nordst.) W. & G.S. West
53, 66
Cosmarium hammeri var. *protuberans* W. & G.S. West
20, 21, 43, 50, 66, 92
Cosmarium holmiense Lund.
50, 53, 56, 64, 66, 124
Cosmarium holmiense var. *integrum* Lund.
46, 50, 53, 56, 60, 66, 92, 96, 129
Cosmarium holmii Wille
40
Cosmarium hornavense var. *dubovianum* (Lütk.) Růžička
66
Cosmarium humile (Gay) Nordst.
5, 20, 43, 46, 50, 53, 56, 60, 64, 66, 73, 76, 77, 92
Cosmarium humile var. *glabrum* Gutw.
92
Cosmarium humile var. *lacustre* f. *majus* Ir.-Mar.
53
Cosmarium humile var. *striatum* (Boldt) Schmidle
20, 21, 46, 53, 60, 64, 66, 92, 94, 97, 100
Cosmarium humile var. *substriatum* (Nordst.) Schmidle
94
Cosmarium impressulum Elfv.
20, 21, 43, 46, 50, 53, 56, 60, 64, 66, 73, 74, 92, 93, 94, 97, 100
=*C. impressulum* f. *minus* Turn.
60, 64
Cosmarium inconspicuum W. & G.S. West
64, 66, 92, 100
=*C. inconspicuum* f. *minus* Ir.-Mar.
64
Cosmarium intermedium Delp.
43, 50, 56, 64, 66
Cosmarium isthmium W. West
20, 21, 64, 92
Cosmarium isthmium f. *hibernicum* W. West
43, 46, 56, 60, 64, 66, 73, 74

Cosmarium isthmochondrum Nordst.
64
Cosmarium isthmochondrum var. *pergranulatum* W. & G.S. West
20, 60, 64
Cosmarium laeve Rabenh.
20, 21, 56, 66, 74, 92
Cosmarium laeve f. *majus* Ir.-Mar.
66
Cosmarium laeve var. *westii* Krieger & Gerloff
=*C. laeve* var. *septentrionale* Wille
92
Cosmarium lagoense (Nordst.) Nordst.
46
=*C. ornatum* var. *lagoense* Nordst.
60
Cosmarium limnophilum Schmidle
66
Cosmarium lobatum var. *ellipticum* Fritsch & Rich
=*C. contractum* var. *papillatum* W. & G.S. West in Ir.-Mar.
50, 60, 64, 66
Cosmarium lobatum var. *triquetrum* Grönbl.
=*Staurodesmus lobatus* var. *triquetrum* (Grönbl.) Bourrelly
5
Cosmarium logiense Biss.
53, 92, 100
Cosmarium lundellii Delp.
20, 21, 46, 60, 64, 93
Cosmarium lundellii var. *corruptum* (Turn.) W. & G.S. West
64, 66, 74
Cosmarium lundellii var. *corruptum* f. *scrobiculatum* Ir.-Mar.
66
Cosmarium lundellii var. *ellipticum* W. & G.S. West
50, 60, 66
Cosmarium margaritatum (Lund.) Roy & Biss.
1, 20, 21, 29, 32, 40, 43, 46, 50, 53, 56, 60, 64, 66, 73, 74, 88, 92, 94, 99, 100, 105, 124, 125, 126
Cosmarium margaritatum f. *minus* (Boldt) W. & G.S. West
20, 21, 43, 50, 60, 64, 66, 121
Cosmarium margaritatum f. *subrotundatum* W. & G.S. West
20
Cosmarium margaritatum var. *ridibundum* Taylor
20, 21, 46, 60, 66
Cosmarium margaritiferum (Turp.) Ralfs
20, 43, 50, 64, 66, 74, 100
Cosmarium margaritiferum f. *regularius* (Nordst.) W. & G.S. West
66
Cosmarium melanosporum Archer
56
Cosmarium meneghinii Bréb. ex Ralfs
20, 21, 46, 50, 53, 56, 60, 64, 66, 73, 74, 92, 94

Cosmarium microsphinctum Nordst.
46, 50, 60, 66
Cosmarium minimum W. & G.S. West
20, 21, 43, 46, 56, 60, 64, 66, 74, 92 (*Euastrum minimum*), 94, 100
Cosmarium minutissimum Archer
20, 21, 29, 43, 50, 56, 60, 64, 66, 73, 74, 99, 124
Cosmarium minutissimum var. *depressum* Ir.-Mar.
73
Cosmarium moniliforme (Turp.) Ralfs
20, 21, 24, 25, 29, 43, 46, 50, 56, 60, 64, 66, 73, 74, 88, 94, 99, 100, 124 (aussi sous *Staurastrum moniliforme*)
=*C. moniliforme* forma Borge in Ir.-Mar.
66
=*C. moniliforme* f. *panduriforme* Heimerl
21, 43, 46, 50, 53, 56, 60, 64, 66, 92, 94
=*C. moniliforme* f. *punctatum* Lagerh.
43, 60, 66
Cosmarium moniliforme var. *intermedium* Nordst.
66
Cosmarium moniliforme var. *limneticum* W. & G.S. West
46, 94
Cosmarium monomazum var. *polymazum* Nordst.
20, 43, 60, 64, 66, 74
Cosmarium montrealense Croasdale
=*C. bioculatum* forma Ir.-Mar.
43, 64
Cosmarium nasutum Nordst.
54, 60, 64, 97
Cosmarium nasutum f. *granulatum* Nordst.
64
Cosmarium nitidulum De Notaris
50, 60, 66, 74, 92
=*C. subtumidum* var. *klebsii* (Gutw.) W. & G.S. West
56, 64
=*Cosmarium* sp.
43
Cosmarium nitidulum var. *hians* Ir.-Mar.
66
Cosmarium norimbergense Reinsch
20, 21
Cosmarium norimbergense var. *depressum* (W. & G.S. West) Krieger & Gerloff
=*C. norimbergense* f. *depressum* W. & G.S. West
66
Cosmarium norvegicum Strøm
43, 54, 56, 60, 66, 74, 92, 121
Cosmarium novae-semliae var. *sibiricum* Boldt
20, 21, 60, 66
Cosmarium novae-terrae Taylor
46, 60, 66
Cosmarium nudum (Turn.) Gutw.
=*C. taxichondrum* var. *nudum* Turn.
50, 54, 64, 66, 74
Cosmarium nymannianum Grun.
43, 46, 50, 56, 60, 66, 100

Cosmarium obliquum Nordst.
92
Cosmarium obsoletum (Hantzsch) Reinsch
92
Cosmarium obtusatum Schmidle
24, 25, 43, 46, 50, 56, 60, 66, 73, 88, 92, 124
Cosmarium ocellatum Eichl. & Gutw.
20, 21, 46, 56, 60, 66
Cosmarium ocellatum var. *incrassatum* W. & G.S. West
66
Cosmarium ocellatum var. *rotundatum* Fritsch & Rich
20, 21
Cosmarium ochthodes Nordst.
46, 50, 60, 66, 92, 93, 129
Cosmarium ochthodes var. *amoebum* W. West
50, 66, 97
Cosmarium ordinatum f. *luetkemuelleri* Ir.-Mar.
66
Cosmarium ornatum Ralfs
1, 5, 20, 21, 43, 46, 50, 56, 60, 66, 73, 74, 88, 94, 100, 124, 125
Cosmarium ornatum f. *simplex* Ir.-Mar.
66
Cosmarium orthostichum Lund.
20, 21, 43, 50, 60, 66, 100, 121, 124
Cosmarium orthostichum var. *compactum* W. & G.S. West
20
Cosmarium orthostichum var. *pumilum* Lund.
43, 60, 66, 74, 100
Cosmarium ovale Ralfs
20, 21, 43, 44, 46, 50, 56, 60, 66, 73, 74, 82, 92, 94, 100
Cosmarium ovale var. *prescottii* Ir.-Mar.
43, 44, 46, 56, 60, 66, 73
Cosmarium ovale var. *subglabrum* W. & G.S. West
43, 44, 50, 66
Cosmarium pachydermum Lund.
43, 46, 50, 54, 56, 60, 66, 92, 93, 97, 100
Cosmarium pachydermum var. *aethiopicum* W. & G.S. West
43, 56, 66, 74, 94
Cosmarium pachydermum var. *pusillum* Ir.-Mar.
60
Cosmarium pardalis Cohn
50, 56, 66, 73, 74
Cosmarium pericymatium Nordst.
66
Cosmarium pericymatium var. *laeve* Ir.-Mar.
60
Cosmarium perpusillum var. *nanum* (Wille) Krieger & Gerloff
20
=*C. meneghinii* var. *nanum* Wille
21, 53, 66
Cosmarium phaseolus Bréb. ex Ralfs
50, 54, 60, 66, 92, 93, 94, 129

Cosmarium phaseolus f. *minus* Boldt
43, 46, 54, 56, 60, 66, 73, 74, 94
Cosmarium plicatum Reinsch
40, 74, 92 (*Euastrum plicatum*)
Cosmarium pokornyanum (Grun.) W. & G.S. West
46, 54, 56, 60, 92
Cosmarium polygonum (Näg.) Archer
43, 66
Cosmarium portianum Archer
5, 6, 20, 21, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 92, 96, 97, 100, 121, 124, 125
Cosmarium portianum var. *nephroideum* Wittr.
20, 21, 43, 46, 50, 54, 60, 64, 66, 73, 74, 100, 124, 125
Cosmarium portianum var. *orthostichum* Schmidle
4
Cosmarium praegrande Lund.
54, 64, 74
Cosmarium praemorsum Bréb.
66
Cosmarium praemorsum f. *minus* Ir.-Mar.
66
Cosmarium protractum (Näg.) De Bary
1, 20, 40, 43, 46, 50, 56, 60, 64, 66, 74, 88, 94, 97, 121, 124
Cosmarium pseudamoenum Wille
20, 21, 66
Cosmarium pseudamoenum var. *basilare* Nordst.
43, 74
Cosmarium pseudatlanthoideum W. West
50, 66
Cosmarium pseudobroomei Wolle
20, 21, 64, 66
Cosmarium pseudoconnatum Nordst.
5, 20, 21, 43, 46, 50, 56, 60, 64, 66, 74, 100
Cosmarium pseudoconnatum var. *ellipsoideum* W. & G.S. West
5, 43, 74
Cosmarium pseudoexiguum Racib.
46, 50, 60, 64
Cosmarium pseudonitidulum Nordst.
50, 54, 64, 66, 73, 74, 92, 100
Cosmarium pseudonitidulum var. *validum* W. & G.S. West
43, 46, 50, 54, 60, 66, 100
Cosmarium pseudoprotuberans Kirchn.
43, 46, 50, 54, 56, 60, 66, 73, 74, 92, 94, 100, 124
Cosmarium pseudopyramidatum Lund.
20, 21, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 92, 93, 100, 124
=*C. pseudopyramidatum* f. *minus* Lund. in Ir.-Mar.
60
Cosmarium pseudopyramidatum var. *extensum* (Nordst.) Krieger & Gerloff
=*C. variolatum* var. *extensum* Nordst.
66
Cosmarium pseudopyramidatum var. *lentiferum* Taylor
5, 43, 46, 56, 60, 64, 66
Cosmarium pseudoretusum var. *inaequalipellicum* (W. & G.S. West) Krieger & Gerloff
=*C. retusum* var. *inaequalipellicum* W. & G.S. West in Ir.-Mar.
43, 46, 56, 60, 64, 66
Cosmarium pseudotaxichondrum Nordst.
20, 64
Cosmarium pseudotaxichondrum var. *foggii* Taylor
46, 60, 74
Cosmarium pseudotaxichondrum var. *septentrionale* Taylor
43, 46, 60, 64, 74
Cosmarium pseudotaxichondrum var. *trichondrum* Lagerh.
20, 43
Cosmarium punctulatum Bréb.
1, 20, 21, 24, 25, 29, 42, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 88, 92, 93, 94, 97, 99 (aussi sous *C. punctatum*), 100, 117 (*C. punctatum*), 121, 124
Cosmarium punctulatum var. *depressum* Turn.
64
Cosmarium punctulatum var. *granulusculum* (Roy & Biss.) W. & G. S. West
100
Cosmarium punctulatum var. *minus* van Oye & Cornil
66
Cosmarium punctulatum var. *subpunctulatum* (Nordst.) Börg.
4, 20, 21, 40, 43, 46, 54, 56, 60, 64, 66, 73, 74, 92, 94, 124
=*C. subpunctulatum* Nordst.
64
Cosmarium pusillum (Bréb.) Archer
20, 21
Cosmarium pygmaeum Archer
46, 54, 56, 60, 66, 92 (*Euastrum pygmaeum*), 100
Cosmarium pyramidatum Bréb. ex Ralfs
5, 20, 21, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 92 (aussi sous *Euastrum pyramidatum*), 100, 121, 124, 125
=*C. pyramidatum* var. *transitorium* (Heimerl) Ir.-Mar.
21, 43, 46, 50, 56, 60, 64, 66, 73, 74, 100, 124
Cosmarium pyramidatum var. *stenonotum* (Nordst.) Klebs
66
=*C. pseudopyramidatum* var. *stenonotum* Nordst.
43, 64, 66
Cosmarium pyramidatum var. *stephani* Ir.-Mar.
43, 46, 60, 64
Cosmarium quadratulum (Gay) De Toni
43, 50, 54, 56, 60, 64, 66, 73, 100
Cosmarium quadratulum var. *latum* Ir.-Mar.
66

Cosmarium quadratum Ralfs
20, 40, 43, 46, 50, 54, 56, 60, 64, 66, 92, 93, 97, 129
=*C. quadratum* f. *majus* Ir.-Mar.
43, 66
Cosmarium quadrifarium Lund.
20, 21, 50, 60, 64, 66
Cosmarium quadrifarium f. *hexastichum* (Lund.) Nordst.
=*C. quadrifarium* var. *hexastichum* (Lund.) Nordst.
29, 43, 46, 54, 56, 60, 64, 74, 99, 100, 124
Cosmarium quadrifarium f. *octastichum* Nordst.
50, 66
Cosmarium quadrifarium f. *polystichum* W. & G.S. West
56
Cosmarium quadrum Lund.
46, 56, 60, 92
Cosmarium quadrum var. *sublatum* (Nordst.) W. & G.S. West
56, 66
Cosmarium quasillus Lund.
43, 60, 64, 73, 92, 94, 121
Cosmarium quinarium Lund.
20, 21, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 97, 124
Cosmarium quinarium f. *irregulare* Nordst.
20, 43, 50, 60, 64, 66, 74, 100
Cosmarium raciborskianum De Toni
=*C. circulare* Reinsch
43, 46, 50, 53, 60, 64, 66, 73
Cosmarium raciborskii (Racib.) Lagerh.
50, 54, 56, 64, 66, 73, 74
Cosmarium ralfsii Bréb. ex Ralfs
92, 96, 129
Cosmarium ralfsii var. *montanum* Racib.
129
Cosmarium rectangulare Grun.
46, 56, 60, 64, 66, 92, 93, 94
Cosmarium rectangulare var. *hexagonum* (Elfv.) W. & G.S. West
66
Cosmarium rectangulum Reinsch
64
Cosmarium rectosporum Turn.
66
Cosmarium refringens Taylor
43, 50, 56, 60, 64, 66
Cosmarium refringens f. *grande* Bicudo
=*C. refringens* f. *majus* Ir.-Mar.
64
=*C. refringens* var. *majus* Ir.-Mar.
60, 74
Cosmarium refringens var. *minus* Ir.-Mar.
60, 66
Cosmarium regnellii Wille
20, 21, 43, 46, 54, 56, 60, 64, 66, 73, 76, 97, 100, 121
Cosmarium regnellii var. *pseudoregnellii* (Messik.) Krieger & Gerloff
=*C. braunii* var. *pseudoregnellii* Messik.
66
Cosmarium regnesi Reinsch
64, 66, 129
Cosmarium regnesi var. *montanum* Schmidle
43, 50, 56, 60, 64, 66, 100
Cosmarium reinschii Archer
129
Cosmarium reniforme (Ralfs) Archer
5, 20, 21, 24, 25, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 88, 92, 93, 94, 96, 97, 100, 121, 124
Cosmarium reniforme f. *majus* Ir.-Mar.
64
Cosmarium reniforme var. *apertum* W. & G.S. West
73
Cosmarium reniforme var. *compressum* Nordst.
46, 60, 74
Cosmarium reniforme var. *elevatum* W. & G.S. West
50, 54, 66
Cosmarium reniforme var. *laeve* Ir.-Mar.
66
Cosmarium reniforme var. *minus* Ir.-Mar.
64, 66, 74
Cosmarium repandum var. *minus* (W. & G.S. West) Krieger & Gerloff
=*C. repandum* f. *minus* W. & G.S. West
1, 43, 56, 60, 66, 73, 74, 88
Cosmarium retusiforme (Wille) Gutw.
20, 74
=*C. retusiforme* var. *morzinense* Laporte
60, 66
Cosmarium retusum (Perty) Rabenh.
43, 50, 54, 56, 60, 64, 66, 73, 100
Cosmarium retusum var. *quebecense* Ir.-Mar.
43, 56, 60, 66
Cosmarium retusum var. *rectangulare* Ir.-Mar.
50, 60, 66
Cosmarium scoticum W. & G.S. West
54, 64, 66, 74
Cosmarium sexangulare Lund.
20, 21, 24, 25, 43, 56, 60, 64, 66, 73, 88, 92, 94, 129
Cosmarium sexangulare var. *minus* Roy & Biss.
=*C. sexangulare* var. *minimum* Nordst.
66
Cosmarium sexnotatum Gutw.
50, 66
Cosmarium sexnotatum var. *tristriatum* (Lütk.) Schmidle
20, 21, 92
Cosmarium simplicius (W. & G.S. West) Grönbl.
=*C. elegantissimum* var. *simplicius* W. & G.S. West
43, 100
Cosmarium smolandicum Lund.
43, 46, 56, 60, 66, 94

Cosmarium speciosum Lund.
50, 54, 56, 66, 92, 129
Cosmarium speciosum var. *biforme* Nordst.
50, 66
Cosmarium speciosum var. *rostafinskii* (Gutw.) W. & G.S. West
43, 56
Cosmarium speciosum var. *rostafinskii* f. *americanum* (W. & G.S. West) W. & G.S. West
46, 56, 60
Cosmarium speciosum var. *simplex* Nordst.
40, 43, 56, 60, 74, 92
Cosmarium sphagnicolum W. & G.S. West
46, 56, 60, 66, 74
Cosmarium sphalerostichum Nordst.
66, 74
Cosmarium sportella Bréb.
1, 43, 50, 56, 64, 66, 73, 88, 92, 94, 105
Cosmarium sportella var. *subnudum* W. & G.S. West
46, 60
Cosmarium sportella var. *subnudum* f. *minus* Ir.-Mar.
66
Cosmarium subarctoum (Lagerh.) Racib.
54, 93, 129
Cosmarium subcapitulum W. West
20, 21
Cosmarium subcostatum Nordst.
43, 56, 64, 66, 73, 74, 124
Cosmarium subcostatum f. *minus* W. & G.S. West
56
Cosmarium subcostatum var. *beckii* (Gutw.) W. & G.S. West
20, 21, 64, 66, 74
Cosmarium subcrenatum Hantzsch
4, 29, 43, 46, 50, 54, 56, 60, 64, 66, 73, 92, 96, 97, 99, 124, 129
Cosmarium subcrenatum var. *divaricatum* Wille
66
Cosmarium subcrenatum var. *sublaeve* Taylor
46, 60, 64
Cosmarium subcucumis Schmidle
20, 43, 46, 50, 54, 56, 60, 64, 66, 74, 92, 93, 96, 97, 100
Cosmarium subdanicum W. West
56, 66, 73
Cosmarium subdepressum W. & G.S. West
20, 21, 43, 60, 64, 90, 92
Cosmarium subgranatum (Nordst.) Lütk.
=*C. granatum* var. *subgranatum* Nordst.
46, 50, 60, 64, 66, 92, 93
Cosmarium subhieronymusii Whelden
129
Cosmarium subnudiceps W. & G.S. West
46, 50, 60, 64, 66
Cosmarium subpraemorsum Borge
=*C. subpraemorsum* forma Ir.-Mar.
50, 64
=*C. subpraemorsum* f. *minus* Ir.-Mar.
66
Cosmarium subprotumidum Nordst.
46, 54, 60, 64, 92, 94
Cosmarium subprotumidum var. *gregorii* (Roy & Biss.) W. & G.S. West
20, 21
Cosmarium subpulchellum W. & G.S. West
64, 66
Cosmarium subreniforme Nordst.
43, 50, 56, 66, 73, 74, 100
Cosmarium subspeciosum Nordst.
43, 50, 56, 60, 64, 66, 92
Cosmarium subspeciosum var. *validius* Nordst.
43, 50, 64, 66
Cosmarium subtruncatellum f. *maius* Prescott
=*C. canadense* var. *prescottii* Ir.-Mar.
50, 66, 74
Cosmarium subtumidum Nordst.
1, 24, 25, 29, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 88, 92, 93, 94, 99, 100, 117, 121, 124
Cosmarium subundulatum Wille
129
Cosmarium succisum W. West
66, 99
Cosmarium superbum Taylor
46, 56, 60, 64, 66
Cosmarium superbum f. *majus* Ir.-Mar.
66
Cosmarium superbum f. *minus* Ir.-Mar.
66
Cosmarium superbum var. *decoratum* Ir.-Mar.
66
Cosmarium supraspeciosum Wolle
56
Cosmarium taxichondrum Lund.
20, 21, 43, 46, 50, 56, 60, 64, 66, 73, 74, 94, 100, 124
=*C. taxichondrum* forma Lund.
74
Cosmarium taxichondrum var. *angulatum* W. & G.S. West
66
Cosmarium taxichondrum var. *irenee-mariae* Wade
=*C. taxichondrum* var. Ir.-Mar.
43, 73
Cosmarium taxichondrum var. *mauritianum* Ir.-Mar.
66
Cosmarium taxichondrum var. *mucronatum* Ir.-Mar.
60
=*C. taxichondrum* var. Ir.-Mar.
43
Cosmarium taxichondrum var. *subundulatum* Boldt
66
Cosmarium taxichondrum var. *truncatum* Ir.-Mar.
60
Cosmarium tenue Archer
20, 21, 43, 46, 50, 54, 56, 60, 64, 66, 73, 74, 92, 93, 94, 124

Cosmarium tenue var. *depressum* Ir.-Mar.
60, 64
Cosmarium tessellatum (Delp.) Nordst.
50, 66
Cosmarium tetragonun var. *intermedium* Boldt
=*C. tetragonun* var. *davidsonii* (Roy & Biss.) W. & G.S. West
66
Cosmarium tetragonun var. *lundellii* Cooke
92
Cosmarium tetraophthalmum (Kütz.) Ralfs
46, 54, 56, 60, 64, 66, 92, 93, 97
Cosmarium thwaitesii var. *penioides* Klebs
46, 60, 64, 74
Cosmarium tinctum Ralfs
64, 74, 100
Cosmarium tithophorum Nordst.
60
Cosmarium trachypleurum Lund.
93
Cosmarium trifluviense Ir.-Mar.
73
Cosmarium trilobulatum Reinsch
94
=*C. trilobulatum* forma W. & G.S. West
66
Cosmarium trilobulatum var. *abscissum* (Schmidle) Krieger & Gerloff
=*C. retusiforme* f. *abscissum* (Schmidle) Borge
66
Cosmarium triplicatum Wolle
43, 46, 56, 60, 64, 66, 73, 100
Cosmarium triplicatum f. *majus* Ir.-Mar.
73
Cosmarium truncatellum Perty
66
Cosmarium trutum Ir.-Mar.
66
Cosmarium tuddalense Strøm
50, 60, 66, 74, 92, 93, 94
Cosmarium tumidum Lund.
20, 21, 24, 25, 29, 43, 46, 50, 54, 60, 64, 66, 73, 74, 88, 92, 98, 99, 100, 121, 124
Cosmarium tumidum f. *subrectangulare* W. & G.S. West
60
Cosmarium tumidum f. *subtriangularis* W. & G.S. West
64
Cosmarium turpinii Bréb.
40, 43, 50, 56, 64, 66, 73, 74, 92, 93, 94, 97, 105, 121, 129
Cosmarium turpinii var. *eximium* W. & G.S. West
43, 64, 92
Cosmarium turpinii var. *podolicum* Gutw.
43, 64, 92, 94
Cosmarium umbilicatum Lütk.
46, 60
Cosmarium undulatum Corda ex Ralfs
54, 56, 64, 92, 96, 129
Cosmarium undulatum var. *circulare* Ir.-Mar.
66
Cosmarium undulatum var. *minutum* Wittr.
46, 60, 64
Cosmarium undulatum var. *wollei* W. West
50, 64, 66, 92
=*C. undulatum* var. *crenulatum* Wolle
50, 54, 56, 64, 66, 73, 94
Cosmarium ungerianum var. *bohemicum* Lütk.
73
Cosmarium variolatum Lund.
60, 64, 66
Cosmarium venustum (Bréb.) Archer
20, 21, 43, 46, 50, 56, 60, 64, 66, 73, 90, 92
Cosmarium venustum f. *minus* Wille
66
Cosmarium venustum var. *excavatum* (Eichl. & Gutw.) W. & G.S. West
5
Cosmarium venustum var. *hypohexagonum* W. West
46, 56, 60, 66
Cosmarium vexatum W. West
46
Cosmarium vexatum var. *quebecense* Ir.-Mar.
56, 60
Cosmarium vitiosum Scott & Grönbl.
=*C. paulense* (Börg.) Johnson
66
Cosmarium zonatum Lund.
46, 60
Cosmarium spp.
20, 22, 23, 24, 29, 32, 39, 42, 87, 92, 95, 99, 106, 109, 110, 111, 112, 121, 124, 125, 126
=*Penium denticulatum* Ir.-Mar.
62
Cosmocladium constrictum (Archer) Archer
20, 97
Cosmocladium pulchellum Bréb.
94
Cosmocladium pusillum Hilse
92, 94
Cosmocladium saxonicum De Bary
20, 21
Cosmocladium spp.
20, 94
Desmidium aptogonum Bréb.
5, 20, 21, 43, 46, 52, 59, 60, 63, 73, 74, 92, 93, 94, 99, 100, 109, 117, 124
Desmidium aptogonum var. *acutius* Nordst.
43, 46, 60, 63, 74, 124
Desmidium aptogonum var. *ehrenbergii* Kütz.
43, 54, 63, 74, 100
Desmidium baileyi (Ralfs) Nordst.
5, 6, 20, 21, 29, 43, 46, 52, 54, 59, 60, 63, 73, 74, 97, 99, 100, 110, 112, 124, 125, 126
Desmidium coarctatum Nordst.
5, 20, 21, 46, 60, 63, 99, 117, 124

Desmidium elegans (Racib.) Grönbl.
=*D. quadrum* var. *doliiforme* Taylor
60 (sous *D. quadratum*)
Desmidium graciliceps (Nordst.) Lagerh.
60 (*D. gracilleps*), 74 (*D. gracilleps*)
Desmidium grevillii (Kütz.) De Bary
5, 6, 20, 21, 43, 46, 52, 54, 59, 60, 63, 74, 87, 100
Desmidium longatum Wolle
60
Desmidium pseudostreptonema W. & G.S. West
46, 60
Desmidium quadrangulatum Ralfs
9
=*D. swartzii* var. *quadrangulatum* (Ralfs) Roy
63
Desmidium quadratum Nordst.
20, 92, 100
Desmidium swartzii (C. Ag.) C. Ag. ex Ralfs
5, 6, 20, 21, 43, 46, 52, 54, 59, 63, 73, 74, 92, 94, 96, 97, 100, 110, 112, 124
Desmidium swartzii f. *punctatum* Ir.-Mar.
43
Desmidium swartzii var. *amblyodon* (Itz.) Rabenh.
43, 54, 59, 63, 73, 100, 124
Desmidium spp.
20, 22, 23, 39, 124, 125, 126
Docidium baculum Bréb. ex Ralfs
20, 21, 43, 45, 59, 60, 63, 70, 73, 74
Docidium undulatum Bail.
5, 20, 43, 45, 49, 60, 63, 70, 73, 74, 100
Docidium undulatum f. *perundulatum* W. & G.S. West
43, 45, 60, 63, 74
Docidium undulatum var. *dilatatum* (Cleve) W. & G.S. West
5, 20, 45, 60, 63
Euastrum aboense Elfv.
43, 45, 60, 65, 71
Euastrum abruptum Nordst.
20, 21, 65, 70, 71, 73, 74, 99, 124
Euastrum abruptum var. *lagoense* (Nordst.) Krieger
=*E. abruptum* f. *minus* W. & G.S. West
29, 43, 49, 54, 57, 60, 65, 70, 71, 73, 74, 99, 100, 124, 125
Euastrum acanthophorum Turn.
20, 21
Euastrum affine Ralfs
20, 21, 43, 45, 49, 57, 60, 65, 70, 71, 74, 100, 110, 112, 124
Euastrum ampullaceum Ralfs
20, 21, 43, 45, 49, 60, 65, 70, 71, 73, 74, 100, 124
Euastrum ampullaceum f. *latum* Ir.-Mar.
60, 65, 70
Euastrum ansatum Ehrenb. ex Ralfs
5, 20, 21, 43, 45, 49, 57, 60, 65, 70, 71, 74, 87, 100, 111
=*E. didelta* f. *longicolle* Ir.-Mar.
71
Euastrum ansatum var. *dideltiforme* Ducellier
71
Euastrum ansatum var. *laticeps* Borge
20, 21
Euastrum ansatum var. *pyxidatum* Delp.
43, 49, 57, 71
Euastrum ansatum var. *subconcavum* Prescott
=*E. didelta* var. *intermedium* Ducellier
71
Euastrum attenuatum Wolle
20, 21, 43, 45, 57, 60, 65, 71, 74, 100
Euastrum bidentatum Näg.
6, 20, 21, 40, 43, 45, 49, 54, 57, 65, 71, 73, 74, 92, 93, 94, 96, 97, 100, 124, 126, 129
=*E. pictum* var. *subrectangulare* W. & G.S. West
60, 65
=*E. rostratum* Ralfs ex Ralfs
129
Euastrum bidentatum f. *latum* Ir.-Mar.
71
Euastrum bidentatum var. *rotundatum* Ir.-Mar.
71
Euastrum bidentatum var. *speciosum* (Boldt) Schmidle
20, 21, 49, 71
Euastrum binale (Turp.) Ehrenb. ex Ralfs
20, 21, 29, 43, 45, 54, 57, 60, 65, 70, 71, 73, 92, 93, 99, 100 (aussi sous *Cosmarium binale*), 121, 124, 125, 126, 129
Euastrum binale f. *minus* W. West
20, 43, 54, 65, 71, 73, 100
=*E. binale* var. *minus* (W. West) Krieger
21
Euastrum binale var. *gutwinskii* (Schmidle) Krieger
20, 100, 129
=*E. binale* f. *gutwinskii* Schmidle
43, 45, 49, 57, 60, 65, 71, 73, 92, 93, 124
Euastrum binale var. *hians* (W. West) Krieger
20, 21
=*E. binale* f. *hians* W. West
43, 45, 49, 57, 60, 65, 70, 71
Euastrum binale var. *sectum* Turn.
129
Euastrum bipapillatum Grönbl.
20, 21
Euastrum boldtii Schmidle
65
=*E. boldtii* var. *isthmochondrum* Grönbl.
71
Euastrum ciastonii Racib.
20, 21, 43, 45, 49, 57, 60, 65, 71, 100
Euastrum ciastonii f. *hians* Ir.-Mar.
60, 65
Euastrum ciastonii f. *minus* Ir.-Mar.
71
Euastrum cornubiense W. & G.S. West
54, 70
Euastrum crassicolle Lund.
43, 65

Euastrum crassum (Bréb.) Ralfs
20, 21, 43, 45, 49, 54, 57, 60, 65, 71, 73, 74, 92, 99, 100, 117, 124
Euastrum crassum var. *michiganense* Prescott
20, 70, 74
Euastrum crassum var. *microcephalum* Krieger
74
Euastrum crassum var. *scrobiculatum* Lund.
5, 43, 45, 60, 65, 74, 100
=*E. crassum* var. *taturnii* W. & G.S. West
74
=*E. crassum* var. *taturnii* f. *allorgei* Laporte
45, 49, 57, 60, 65, 71
Euastrum crispulum (Nordst.) W. & G.S. West
71
Euastrum cuneatum Jenner ex Ralfs
20, 21, 45
Euastrum denticulatum (Kirchn.) Gay
5, 20, 21, 45, 57, 60, 65, 70, 71, 74, 92, 94, 97, 124, 126
Euastrum denticulatum var. *angusticeps* Grönbl.
71
Euastrum denticulatum var. *bidentatum* (Ir.-Mar.) Prescott
=*E. sinuosum* var. *bidentatum* Ir.-Mar.
72
Euastrum denticulatum var. *nordstedtianum* Ir.-Mar.
49, 60, 65, 71, 73, 74
Euastrum denticulatum var. *quadrifarium* Krieger
20, 21, 70, 74
Euastrum didelta (Turp.) Ralfs
6, 20, 21, 29, 43, 45, 49, 54, 57, 60, 65, 70, 71, 73, 74, 87, 92, 96, 99, 100, 124, 125
=*E. didelta* var. *ansatiforme* Schmidle sensu Ir.-Mar.
43, 49, 57, 60, 65, 70, 71, 74, 100
=*E. didelta* forma Ir.-Mar.
43
Euastrum didelta f. *scrobiculatum* Nordst.
=*E. didelta* var. *scrobiculatum* (Nordst.) Ir-Mar.
65
Euastrum didelta var. *crassum* (Prescott & Scott) Förster
=*E. obesum* var. *crassum* Prescott & Scott
60, 65, 74
Euastrum didelta var. *everettensiforme* (Wolle) Ducellier
71
Euastrum divaricatum Lund.
20, 21, 29, 43, 45, 54, 57, 60, 65, 70, 71, 74, 76, 99, 100, 124
Euastrum divaricatum var. *elevatum* (Ir.-Mar.) Prescott
=*E. divaricatum* var. *inerme* Ir.-Mar.
71
Euastrum divaricatum var. *spinosum* (Ir.-Mar.) Prescott
=*E. candianum* var. *munitum* f. *canadianum* Ir.-Mar.
71
Euastrum doliforme W. & G.S. West
92
Euastrum dubium Näg.
20, 21, 27, 28, 29, 43, 49, 54, 57, 60, 65, 71, 73, 74, 92, 97, 99, 124, 129
Euastrum dubium var. *canadense* Ir.-Mar.
73
Euastrum dubium var. *latum* Krieger
70
Euastrum elegans (Bréb.) Ralfs
20, 21, 29, 43, 45, 49, 54, 57, 60, 65, 70, 71, 73, 74, 99, 116, 117, 121, 124, 125, 126, 129
=*E. elegans* var. *bidentatum* (Näg.) Jacobsen
43, 54, 65, 70, 74, 124
Euastrum elegans var. *compactum* (Wolle) Krieger
=*E. compactum* Wolle
49, 54, 60, 65, 71, 74
=?*E. compactum* var. *majus* Lagerh.
71
Euastrum elegans var. *novae-semliae* Wille
60, 65, 71
Euastrum elegans var. *ornatum* W. West
20, 29, 43, 45, 54, 100, 124
Euastrum elegans var. *pseudelegans* f. *quebecense* (Ir.-Mar.) Prescott
=*E. elegans* var. *quebecense* Ir.-Mar.
65
Euastrum elobatum (Lund.) Roy & Biss.
92
=*E. binale* var. *elobatum* Lund.
65, 71
Euastrum everettense Wolle
20, 21, 43, 45, 49, 60, 65, 71, 100
?*Euastrum evolutum* f. *minor* W. & G.S. West
45, 49, 60, 65, 71
?*Euastrum evolutum* var. *incudiforme* (Börg.) W. & G.S. West
20, 21
Euastrum fissum W. & G.S. West
20, 21, 74
Euastrum fissum var. *americanum* Cushman
20, 21, 60, 65, 71, 74
Euastrum fissum var. *decoratum* Scott & Prescott
5
Euastrum gemmatoides Ir.-Mar.
74
Euastrum gemmatum (Bréb.) Ralfs
5, 20, 21, 43, 45, 49, 54, 57, 65, 70, 71, 74, 97, 100, 121
Euastrum glaziovii Börg.
=*E. evolutum* var. *glaziovii* (Börg.) W. & G.S. West
20, 21, 43, 45, 49, 57, 60, 65, 70, 71, 74, 100
Euastrum glaziovii var. *evolutum* (Nordst.) Compère
=*E. evolutum* (Nordst.) W. & G.S. West
20, 21, 43, 45, 49, 57, 60, 65, 70, 71, 74, 100
Euastrum glaziovii var. *integrius* (W. & G.S. West) Compère

=*E. evolutum* var. *integrius* W. & G.S. West
20, 21, 43, 45, 49, 57, 60, 65, 70, 71, 74, 100
Euastrum humerosum Ralfs
5, 20, 21, 24, 25, 43, 45, 49, 54, 57, 60, 65, 71, 74, 82, 88, 100
=*E. humerosum* f. *scrobiculatum* Nordst.
74
Euastrum humerosum var. *evolutum* Krieger
49, 65, 71, 74
Euastrum inerme (Ralfs) Lund.
45, 60, 65, 129
Euastrum infernum Ir.-Mar.
65
Euastrum informe Borge
45, 60, 65, 71, 74
Euastrum insigne Hass. ex Ralfs
20, 45, 49, 57, 60, 65, 70, 71, 73, 74, 100
Euastrum insigne var. *lobulatum* Prescott & Scott
49, 60, 65, 70, 71, 74
Euastrum insigne var. *lobulatum* f. *acutilobum* Scott & Prescott
124
Euastrum insigne var. *lobulatum* f. *taylorii* Prescott & Scott
49, 60, 65, 71, 74
Euastrum insigne var. *pulchrum* Krieger
20
Euastrum insulare (Wittr.) Roy
20, 21, 43, 45, 54, 57, 60, 65, 70, 71, 73, 74, 92, 93, 94, 97, 99 (*E. innulare*), 100, 117 (*E. innulare*), 121, 124, 126 (sous *Eunotia insulare*)
Euastrum intermedium Cleve
49, 60, 65, 71, 74
Euastrum intermedium var. *longicolle* Borge
43, 45, 65, 74
Euastrum intermedium var. *scrobiculatum* (Schmidle) Krieger
20, 21, 100
Euastrum intermedium var. *validum* W. & G.S. West
43, 45, 49, 60, 65, 71, 74, 100
Euastrum johnsonii var. *porrectum* (Borge) Ir.-Mar.
49, 57, 71
Euastrum lapponicum Schmidle
20, 21, 43, 49, 57, 60, 65, 71, 74, 100, 126
Euastrum lapponicum var. *mauritianum* Prescott
=*E. dubium* f. *mauritianum* Ir.-Mar.
71
Euastrum lapponicum var. *quebecense* Ir.-Mar.
71
Euastrum luetkemuelleri Ducellier
71
Euastrum marianopoliense Ir.-Mar.
43
Euastrum moniforme (Turp.) Ralfs
100
Euastrum montanum W. & G.S. West
20, 40, 49, 54, 70, 71, 73, 74, 129
Euastrum obesum Joshua
20, 21, 29, 45, 57, 70, 99, 124
Euastrum obesum var. *subangulare* W. & G.S. West
45, 60, 65, 71
=*E. obesum* forma Ir.-Mar.
43, 65, 74
Euastrum oblongum (Grev.) Ralfs
6, 20, 21, 29, 43, 45, 49, 54, 57, 60, 65, 70, 71, 73, 74, 92, 97, 99, 124
Euastrum oblongum var. *cephalophorum* W. West
70
Euastrum oblongum var. *depauperatum* W. & G.S. West
20, 21, 43, 100
Euastrum oblongum var. *ellipticum* (Ir.-Mar.) Ir.-Mar.
71
=*E. oblongum* f. *ellipticum* Ir.-Mar.
49, 60, 65, 70, 74
Euastrum occidentale W. & G.S. West
96
Euastrum oculatum Börg.
20
Euastrum oculatum var. *tonsum* W. & G.S. West
43, 100
Euastrum oculatum var. *tonsum* f. *mucronatum* Ir.-Mar.
60, 65, 71
Euastrum pectinatum Bréb. ex Ralfs
20, 70
Euastrum pectinatum f. *elongatum* Ir.-Mar.
65
Euastrum pectinatum var. *brachylobum* Wittr.
5, 20, 21, 43, 45, 54, 57, 65, 70, 71, 74, 124, 126
Euastrum pectinatum var. *inevolutum* W. & G.S. West
70
Euastrum pingue Elfv.
45, 57, 60, 65, 70, 73
Euastrum pinnatum Ralfs
20, 21, 43, 45, 49, 57, 60, 65, 70, 71, 74, 100
Euastrum pinnatum var. *pres-scottii* Ir.-Mar.
72
Euastrum pseudoboldtii Grönbl.
74
Euastrum pulchellum Bréb.
6, 20, 45, 49, 60, 65, 72, 74, 92, 94
Euastrum pulchellum var. *retusum* W. & G.S. West
20, 21, 72, 100
Euastrum quebecense Ir.-Mar.
43, 45, 73, 92, 107
Euastrum rimula Ir.-Mar.
72
Euastrum sibiricum Boldt
60, 65
Euastrum sibiricum var. *exsectum* (Grönbl.) Krieger
60, 65, 72
Euastrum sinuosum Lenorm.
20, 21, 43, 49, 57, 60, 65, 72, 73, 74, 100
Euastrum sinuosum var. *reductum* W. & G.S. West
20, 21, 43, 45, 49, 57, 60, 65, 70, 72, 73, 74

Euastrum sinuosum var. *subjenneri* W. & G.S. West
72
Euastrum sphyroides var. *intermedium* Lütk.
70
Euastrum subhexalobum W. & G.S. West
43, 45, 57, 60, 65, 72
Euastrum sublobatum Bréb. ex Ralfs
20, 60, 65
Euastrum trigibberum W. & G.S. West
20, 21, 49, 65, 70, 72
Euastrum turneri W. West
20, 45, 49, 57, 60, 65, 72, 74
Euastrum turneri f. *laeve* Ir.-Mar.
72
Euastrum urnaforme Wolle
20, 21, 43, 45, 57, 60, 65, 70, 72, 100
Euastrum urnaforme f. *rostratum* Ir.-Mar.
72
Euastrum validum W. & G.S. West
43, 45, 49, 57, 60, 65, 72, 74, 100
Euastrum ventricosum Lund.
60, 65, 92
Euastrum verrucosum Ehrenb. ex Ralfs
6, 20, 21, 43, 45, 49, 57, 60, 65, 70, 72, 73, 74, 87, 92, 94, 96, 97
Euastrum verrucosum var. *alatum* Wolle
20, 21, 43, 45, 49, 57, 60, 65, 70, 72, 73, 74, 97, 100
=*E. verrucosum* var. *alatum* f. *minus* (Lobik) Kossinsk.
21, 29 (*E. verrucosum* f. *minus*), 43, 45, 49, 54, 57, 60, 65, 70, 72, 99 (*E.verrucosum* f. *minus*), 124 (*E. verrucosum* f. *minus*)
Euastrum verrucosum var. *alatum* f. *rostratum* Ir.-Mar.
49, 72
Euastrum verrucosum var. *apiculatum* Istvanffi
45, 70, 72, 74
Euastrum verrucosum var. *coarctatum* Delp.
45, 49, 57, 60, 65, 70, 72
=*E. verrucosum* var. *reductum* Nordst.
45, 49, 57, 60, 65, 72, 74
Euastrum verrucosum var. *crassum* (Ir.-Mar.) Prescott
=*E. verrucosum* var. *alatum* forma Ir.-Mar.
60
Euastrum verrucosum var. *crassum* f. *angustum* (Ir.-Mar.) Prescott
=*E. verrucosum* var. *alatum* forma Ir.-Mar.
60
Euastrum verrucosum var. *dalbisii* f. *minus* Prescott & Scott
60, 65
Euastrum verrucosum var. *rhomboideum* Lund.
5, 65
Euastrum verrucosum var. *ricardii* Ir.-Mar.
49, 72, 74
Euastrum verrucosum var. *subalatum* Huber-Pestalozzi
70, 74
Euastrum verrucosum var. *willei* Ir.-Mar.
65
Euastrum wollei Lagerh.
60, 65
=*E. wollei* var. *cuspidatum* De Toni
45
Euastrum wollei var. *pearlingtonense* Prescott & Scott
60, 65, 74
Euastrum spp.
20, 23, 29, 87, 95, 99, 116, 124, 125, 126
Groenbladia neglecta (Racib.) Teil.
5, 20, 21
=*Hyalotheca neglecta* Racib.
1, 29, 43, 60, 63, 74, 99, 109, 110, 112, 124, 125
Groenbladia undulata (Nordst.) Förster
20
=*Hyalotheca undulata* Nordst.
21, 43, 54, 60, 63, 109, 110, 112, 121
Hyalotheca dissiliens (J.E. Sm.) Bréb. ex Ralfs
5, 6, 20, 21, 29, 40, 43, 47, 51, 54, 59, 60, 63, 73, 74, 87, 88, 90, 92, 93, 96, 97, 99, 100, 110, 112, 117, 124, 125, 126, 129
=*H. dissiliens* var. *major* Delp.
74
=*H. dissiliens* var. *minor* Delp.
74
Hyalotheca dissiliens f. *tridentula* (Nordst.) Boldt
43
Hyalotheca dissiliens var. *hians* Wolle
29 (f. *hians*), 43, 63, 99 (f. *hians*), 100, 124 (f. *hians*)
Hyalotheca dissiliens var. *tatrica* Racib.
20, 43, 47, 54, 60
Hyalotheca laevicincta Taylor
20, 21
Hyalotheca mucosa (Mertens) Ehrenb. ex Ralfs
1, 5, 20, 21, 29, 43, 47, 51, 54, 59, 60, 63, 73, 74, 88, 97, 99, 100, 110, 112, 124
Hyalotheca spp.
20, 124, 125
Micrasterias abrupta W. & G.S. West
7, 43, 45, 60
Micrasterias americana (Ehrenb.) Ralfs
20, 21, 24, 25, 43, 45, 51, 54, 57, 60, 67, 70, 73, 74, 82, 88, 92, 94, 96, 97, 100, 101
Micrasterias americana f. *boldtii* (Gutw.) Croasdale
=*M. americana* var. *boldtii* Gutw.
57
Micrasterias americana f. *calcarata* Croasdale
=*M. americana* f. *taylorii* Ir.-Mar.
51, 67
Micrasterias americana f. *gaspensis* Ir.-Mar.
70
Micrasterias americana f. *lewisiana* W. West
45, 60, 67
Micrasterias apiculata (Ehrenb.) Ralfs
6, 43, 45, 60, 67, 70, 74, 92, 98, 100

Micrasterias apiculata var. *fimbriata* (Ralfs) Nordst.
20, 21, 29, 43, 45, 54, 57, 60, 67, 74, 98, 99, 124
=*M. fimbriata* Ralfs
21, 82, 87
Micrasterias apiculata var. *fimbriata* f. *depauperata* Ir.-Mar.
57, 67
Micrasterias apiculata var. *fimbriata* f. *spinosa* (Biss.) W. & G.S. West
20, 21, 43, 45, 51, 57, 60, 67, 97, 100
=*M. fimbriata* var. *spinosa* Biss.
5, 21
Micrasterias arcuata Bail.
45, 60, 73, 74, 99, 117, 124
Micrasterias arcuata var. *expansa* (Bail.) Nordst.
=*M. expansa* Bail.
15, 45, 51, 57, 60, 67, 73, 74
Micrasterias arcuata var. *gracilis* (Bail.) W. & G.S. West
45, 60
Micrasterias arcuata var. *robusta* Borge
=*M. expansa* var. *robusta* Borge
51, 57, 67, 74
Micrasterias brachyptera Lund.
=*M. apiculata* var. *brachyptera* (Lund.) W. & G.S. West
45, 54, 60
=*M. apiculata* var. *simplex* Ir.-Mar.
60
Micrasterias conferta Lund.
43, 45, 51, 57, 60, 67, 73, 74
Micrasterias conferta var. *hamata* Wolle
7, 20, 21, 43, 45, 51, 54, 57, 60, 67, 74, 100
Micrasterias crux-melitensis (Ehrenb.) Ralfs
7, 43, 45, 51, 54, 57, 60, 67, 70, 73, 74, 92
Micrasterias crux-melitensis f. *spinosa* (Roll) Croasdale
=*M. crux-melitensis* var. *spinosa* Roll
43, 45, 51, 60, 67
Micrasterias denticulata Bréb. ex Ralfs
7, 20, 21, 29, 43, 45, 51, 54, 57, 60, 67, 70, 74, 96, 98, 99, 100, 124
Micrasterias denticulata var. *angulosa* (Hantzsch) W. & G.S. West
45, 51, 57, 60, 67
=*M. denticulata* var. *angustosinuata* Gay
54
Micrasterias denticulata var. *granulosa* Ir.-Mar.
57, 60
Micrasterias denticulata var. *taylorii* Krieger
60
Micrasterias depauperata Nordst.
45
Micrasterias depauperata var. *kitchelii* (Wolle) W. & G.S. West
20, 21, 100
Micrasterias depauperata var. *wollei* Cushman
7, 43, 45, 57, 60, 67, 70, 74, 100
Micrasterias depauperata var. *wollei* f. *apiculata* Ir.-Mar.
60
Micrasterias floridensis f. *canadensis* (Ir.-Mar.) Croasdale
=*M. johnsonii* var. *papillata* f. *canadensis* Ir.-Mar.
67
Micrasterias foliacea Bail. ex Ralfs
5, 9, 20, 43, 45, 57, 60, 67, 74, 100
Micrasterias furcata Ag. ex Ralfs
=*M. radiata* Hass.
5, 6, 20, 21, 43, 45, 51, 54, 57, 60, 67, 70, 73, 74, 92, 94, 96, 98, 100, 124
=*M. radiata* f. *deflexa* Ir.-Mar.
57, 60, 67, 74
=*M. radiata* var. *simplex* (Wolle) G.M. Sm.
21, 43, 45, 51, 57, 60, 67, 74
=*M. radiata* forma Ir.-Mar.
43
Micrasterias furcata var. *dichotoma* (Wolle) Růžička
=*M. radiata* var. *dichotoma* (Wolle) Cushman
51, 67, 74
Micrasterias furcata var. *smithii* Růžička
=?*M. radiata* var. *gracillima* G.M. Sm.
5, 20, 21, 43, 45, 51, 54, 57, 60, 67, 70, 74, 98, 100
Micrasterias jenneri Ralfs
51, 67
Micrasterias johnsonii W. & G.S. West
20, 60, 67, 74
Micrasterias johnsonii var. *bipapillata* Taylor
45, 60
Micrasterias johnsonii var. *ranoides* (Salisb.) Krieger
20, 21, 100
Micrasterias laticeps Nordst.
5, 20, 21, 43, 45, 51, 54, 57, 60, 67, 70, 73, 92, 94, 97, 100
Micrasterias mahabuleshwarensis Hobson
7, 20, 43, 45, 67, 92
=*M. mahabuleshwarensis* f. *dichotoma* G.M. Sm.
43, 67, 70
=*M. mahabuleshwarensis* var. *dichotoma* (G.M. Sm.) Krieger
21
Micrasterias mahabuleshwarensis var. *ringens* (Bail.) Krieger
5, 20
=*M. mahabuleshwarensis* var. *serrulata* (Wolle) G.M. Sm.
7, 43, 67
=*M. ringens* Bail.
21
Micrasterias mahabuleshwarensis var. *wallichii* (Grun.) W. & G.S. West
=*M. americana* var. *hermanniana* Reinsch
45, 57, 60

Micrasterias muricata (Bail.) Ralfs
5, 7, 20, 21, 43, 45, 51, 54, 57, 60, 67, 70, 74, 87, 100, 109, 124
Micrasterias muricata var. *laevigata* Ir.-Mar.
60, 67, 74
Micrasterias muricata var. *tumida* W. & G.S. West
20, 43
Micrasterias nordstedtiana Wolle
5, 20, 45, 60, 67
Micrasterias novae-terrae (Cushman) Krieger
60
=*M. conferta* var. *novae-terrae* Cushman
45
Micrasterias novae-terrae var. *speciosa* (Wolle) Krieger & Bourrelly
=*M. speciosa* Wolle
45, 60
Micrasterias papillifera Bréb. ex Ralfs
4, 20, 29, 43, 45, 51, 54, 57, 60, 67, 70, 73, 74, 92, 96, 97, 98, 99, 100, 124
=*M. papillifera* var. *varvicensis* Turn.
45, 57, 60
=*M. papillifera* var. *verrucosa* Schmidle
45, 60
=*M. sol* var. *ornata* Nordst.
21
Micrasterias papillifera var. *glabra* Nordst.
51, 54, 67
Micrasterias papillifera var. *rousseauiana* Ir.-Mar.
54
Micrasterias pinnatifida (Kütz.) Ralfs
5, 7, 20, 21, 32, 43, 45, 51, 54, 57, 60, 67, 70, 73, 74, 92, 98, 100, 124, 125, 126
Micrasterias pinnatifida f. *furcata* (Krieger) Croasdale
=*M. pinnatifida* var. *divisa* W. West
45, 51, 57, 60, 67
Micrasterias pinnatifida f. *inflata* (Wolle) Croasdale
=*M. pinnatifida* var. *inflata* Wolle
43, 45, 57, 60, 67, 74
=*M. pinnatifida* var. *inflata* f. *ornata* Ir.-Mar.
43, 45, 57, 60, 67, 74
Micrasterias pinnatifida var. *pseudoscitans* Grönbl.
45, 54, 57, 60
=*M. pinnatifida* f. *rhomboidea* Brunel
13, 43, 124 (var. *rhomboidea*)
Micrasterias radiosa Ralfs
7, 20, 45, 51, 54, 57, 60, 67, 70, 73, 74, 87, 100, 124
=*M. radiosa* var. *taylorii* Ir.-Mar.
60, 67, 74
=*M. sol* (Ehrenb.) Kütz.
92
Micrasterias radiosa f. *mistassiniensis* Ir.-Mar.
54, 57
Micrasterias radiosa var. *elegantior* (G.S. West) Croasdale
20
=*M. radiosa* var. *ornata* f. *elegantior* (G.S. West) G.M. Sm.
43, 45, 51, 54, 57, 60, 67, 74, 100
=*M. sol* var. *elegantior* G.S. West
5, 21
=*M. sol* var. *elegantior* f. *glabra* Bourrelly
5
Micrasterias radiosa var. *murrayi* (W. & G.S. West) V. & P. Allorge
74
=*M. murrayi* W. & G.S. West
74
Micrasterias radiosa var. *murrayi* f. *glabra* (Ir.-Mar.) Croasdale
=*M. murrayi* var. *glabra* Ir.-Mar.
54
Micrasterias radiosa var. *ornata* Nordst.
29, 43, 45, 51, 54, 57, 60, 67, 73, 74, 98, 99, 124
=*M. radiosa* f. *papillifera* Ir.-Mar.
57, 60
Micrasterias radiosa var. *ornata* f. *laurentiana* Brunel
13, 100
=*M. radiosa* f. *laurentiana* Brunel
57, 70
Micrasterias radiosa var. *ornata* f. *taylorii* Ir.-Mar.
74
Micrasterias radiosa var. *punctata* W. West
45, 57, 60, 67
Micrasterias radiosa var. *swainei* (Hastings) W. & G.S. West
45
=*M. radiosa* var. *extensa* Prescott & Scott
60, 67, 70
=*M. swainei* Hastings
60, 67, 74
Micrasterias rotata (Grev.) Ralfs
7, 20, 21, 43, 45, 51, 54, 57, 60, 67, 70, 73, 74, 92, 95, 96, 98, 100, 109
=*M. rotata* f. *inermis* Ir.-Mar.
57, 67
=*M. rotata* f. *nuda* (Wolle) Ir.-Mar.
21, 43, 45, 51, 54, 60, 67, 73, 74, 100
Micrasterias rotata f. *clausa* Ir.-Mar.
57
Micrasterias rotata f. *evoluta* Turn.
74
Micrasterias rotata var. *japonica* Fujisawa
=*M. denticulata* f. *mucronata* Ir.-Mar.
57
Micrasterias tetraptera W. & G.S. West
45, 60
Micrasterias tetraptera var. *angulosa* Ir.-Mar.
60, 67
Micrasterias thomasiana Archer
7, 45, 60, 74
Micrasterias torreyi Bail. ex Ralfs
5, 6, 20, 21, 45, 57, 60, 67, 70, 74, 100

=*M. torreyi* f. *punctata* Ir.-Mar.
57, 67, 74
=*M. torreyi* var. *nordstedtiana* (Hieron.) Schmidle
92
Micrasterias torreyi var. *crameri* f. *minor* Ir.-Mar.
74
Micrasterias truncata (Corda) Bréb. ex Ralfs
4, 5, 6, 20, 21, 43, 45, 51, 54, 57, 60, 67, 70, 73, 74, 92, 93, 94, 100, 124, 125
=*M. truncata* var. *quebecensis* Ir.-Mar.
57
Micrasterias truncata f. *neodamensis* (A. Br.) Dick
=*M. decemdentata* (Näg.) Archer
45
=*M. truncata* var. *rectangularis* Ir.-Mar.
67
Micrasterias truncata f. *semiradiata* (Näg.) Cleve
20, 21, 43, 51, 54, 57, 60, 67, 70, 73, 74, 98, 100
Micrasterias truncata f. *tridentata* (Bennett) Croasdale
=*M. truncata* var. *tridentata* Bennett
43, 45, 60
Micrasterias truncata var. *bahusiensis* Wittr.
=*M. truncata* var. *mauritiana* Ir.-Mar.
51, 67
=*M. truncata* var. *mauritiana* f. *triangularis* Ir.-Mar.
51, 67
Micrasterias truncata var. *crenata* (Bréb.) Reinsch
43, 45, 51, 60, 67, 70
Micrasterias truncata var. *turgida* Taylor
51, 67
Micrasterias verrucosa Biss.
10
Micrasterias spp.
20, 32, 45, 124, 126
Onychonema filiforme (Ehrenb.) Roy & Biss.
20, 21, 43, 47, 54, 60, 63, 73, 74, 92, 94, 97, 100
Onychonema laeve Nordst.
73, 92, 94, 118
=*Sphaerozosma laeve* (Nordst.) Thomasson
1, 88
Onychonema laeve var. *latum* W. & G.S. West
43, 63, 73, 76, 100
Onychonema laeve var. *micracanthum* Nordst.
43, 47, 51, 59, 60, 63, 73, 74
Penium cylindrus (Ehrenb.) Bréb. ex Ralfs
20, 70
Penium margaritaceum (Ehrenb.) Bréb. ex Ralfs
6, 20, 43, 45, 49, 54, 59, 60, 62, 63, 70, 73, 74, 94, 97, 100
Penium margaritaceum f. *majus* Ir.-Mar.
60
Penium margaritaceum var. *elongatum* Klebs
70
Penium phymatosporum Nordst.
70
Penium polymorphum Perty
3, 5, 20, 21, 43, 45, 49, 59, 60, 63, 70, 74, 100
Penium silvae-nigrae Rabanus
5
Penium spinulosum (Wolle) Gerrath
20
=*Docidium spinulosum* Wolle
18
=*Pleurotaenium spinosum* (Wolle) Bernard
45
=*Pleurotaenium spinulosum* (Wolle) Brunel
19, 21, 60, 62, 74, 100
Penium spirostriolatum Barker
5, 20, 21, 43, 45, 49, 59, 60, 62, 63, 74, 92, 100
Penium spp.
20, 42, 124, 126
Phymatodocis nordstedtiana Wolle
60, 74
Pleurotaenium baculoides (Roy & Biss.) Playfair
74
=*P. baculiformiceps* Grönbl.
59, 62
Pleurotaenium baculoides var. *brevius* (Skuja) Krieger
20, 21
Pleurotaenium constrictum (Bail.) Wood
20, 21, 43, 45, 60, 62, 70, 74, 98, 100, 110, 112
Pleurotaenium constrictum var. *laeve* Ir.-Mar.
62
Pleurotaenium coronatum (Bréb.) Rabenh.
20, 21, 43, 45, 54, 59, 60, 62, 70, 73, 74, 97, 100, 110, 112
Pleurotaenium coronatum var. *complanatum* Ir.-Mar.
60
Pleurotaenium ehrenbergii (Bréb.) De Bary
5, 6, 20, 21, 29, 43, 45, 49, 54, 59, 60, 62, 70, 73, 74, 92, 93, 96, 97, 98, 99, 100, 110, 112, 124, 125, 126
=*P. ehrenbergii* forma Ir.-Mar.
43
=*P. ehrenbergii* var. *arcuatum* Ir.-Mar.
49, 60, 62, 70, 73, 74
=*P. ehrenbergii* var. *arcuatum* f. *granulatum* Ir.-Mar.
62
=*P. ehrenbergii* var. *granulatum* (Ralfs) W. & G.S. West
21, 43, 49, 54, 60, 62, 70, 74
Pleurotaenium ehrenbergii f. *columellare* Ir.-Mar.
62
Pleurotaenium ehrenbergii f. *rectum* Ir.-Mar.
74
Pleurotaenium ehrenbergii f. *tumidum* (Turn.) Croasdale
=*P. ehrenbergii* var. *tumidum* (Turn.) Ir.-Mar.
62
Pleurotaenium ehrenbergii var. *elongatum* W. West
20, 21, 43, 45, 54, 59, 60, 62, 70, 73, 74, 100
Pleurotaenium ehrenbergii var. *elongatum* f. *minus* Ir.-Mar.
62

Pleurotaenium ehrenbergii var. *undulatum* Schaarschmidt
=*P. paludosum* Ir.-Mar.
62
Pleurotaenium hypocymatium W. & G.S. West
43, 62
Pleurotaenium maximum (Reinsch) Lund.
20, 43, 49, 54, 59, 60, 62, 70, 73, 74, 92
=*P. trabecula* var. *maximum* (Reinsch) Roll
21, 92
Pleurotaenium maximum f. *clavatum* (Ir.-Mar.) Prescott & Croasdale
=*P. maximum* var. *clavatum* Ir.-Mar.
62
Pleurotaenium minutum (Ralfs) Delp.
5, 20, 21, 43, 45, 49, 54, 59, 60, 62, 70, 73, 74, 87, 100, 124, 125
Pleurotaenium minutum f. *maius* (Lund.) Kossinsk.
20
=*P. minutum* f. *majus* Lund.
43, 49, 54, 59, 60, 62, 70, 74, 100
=*P. rectum* Delponte
92
Pleurotaenium minutum var. *crassum* (W. West) Krieger
45
=*Penium crassum* (W. West) Ir.-Mar.
59, 60, 62, 63, 70
=*Penium crassum* f. *inflatum* W. West
59, 60
Pleurotaenium minutum var. *elongatum* (W. & G.S. West) Cederg.
20, 21, 43, 45, 60, 62, 70, 73, 74,
Pleurotaenium minutum var. *gracile* (Wille) Krieger
20, 21, 49, 62, 74
Pleurotaenium minutum var. *groenbladii* (W. & G.S. West) Croasdale
=*P. rectum* var. *rectissimum* (W. & G.S. West) Grönbl.
100
Pleurotaenium minutum var. *latum* Kaiser
74
Pleurotaenium minutum var. *minus* (Racib.) Krieger
=*P. minutum* f. *minus* Racib.
45, 74
Pleurotaenium minutum var. *rectissimum* (W. & G.S. West) Krieger
21
Pleurotaenium nodosum (Bail.) Lund.
20, 21, 43, 45, 59, 60, 62, 70, 74, 98, 100, 110, 112
Pleurotaenium nodosum var. *latum* Ir.-Mar.
62
Pleurotaenium nodulosum (Bréb.) De Bary
20, 43, 45, 59, 60, 62, 70, 73, 74
Pleurotaenium ovatum Nordst.
74
Pleurotaenium polymorphum (Turn.) Ir.-Mar.
62
Pleurotaenium raciborskii f. *maius* Croasdale
=*Pleurotaenium* sp. sensu Ir.-Mar.
43
Pleurotaenium sceptrum (Roy) W. & G.S. West
=*P. tridentulum* (Wolle) W. West
60, 74, 124
Pleurotaenium sceptrum var. *capitatum* (W. West) W. & G.S. West
=*P. tridentulum* var. *capitatum* W. West
60
Pleurotaenium subcoronulatum (Turn.) W. & G.S. West
32, 62, 70, 74
Pleurotaenium subcoronulatum var. *detum* W. & G.S. West
5, 9, 20, 21, 43, 45, 49, 60, 62, 70, 73, 74, 100
Pleurotaenium trabecula (Ehrenb.) Näg.
20, 21, 24, 25, 43, 45, 49, 54, 59, 60, 62, 70, 73, 74, 88, 90, 92, 93, 94, 97, 109, 110, 112, 121, 124, 125, 126
=*P. trabecula* f. *clavatum* (Kütz.) Reinsch
43, 49, 62, 70, 73
Pleurotaenium trabecula f. *metula* (Lagerh.) Croasdale
=*P. metula* var. *canadense* Ir.-Mar.
62
Pleurotaenium trabecula var. *elongatum* Cederg.
20, 21
Pleurotaenium trabecula var. *hutchinsonii* (Turn.) Croasdale
20
Pleurotaenium trabecula var. *rectissimum* W. & G.S. West
20, 49, 62, 74
Pleurotaenium trabecula var. *rectum* (Delp.) W. & G.S. West
20, 21, 29, 43, 45, 49, 54, 59, 60, 62, 70, 73, 74, 99, 100, 124, 125, 126
Pleurotaenium trochiscum W. & G.S. West
20, 74
Pleurotaenium truncatum (Bréb.) Näg.
20, 21, 40, 43, 45, 49, 59, 60, 62, 70, 73, 74, 100
Pleurotaenium truncatum var. *crassum* Boldt
62, 74
Pleurotaenium truncatum var. *crassum* forma Ir.-Mar.
43, 45
Pleurotaenium truncatum var. *crassum* f. *turbiforme* Ir.-Mar.
49, 60, 62, 73
=*P. truncatum* var. *crassum* forma Ir.-Mar.
43
Pleurotaenium truncatum var. *farquharsonii* (Roy) W. & G.S. West
62, 74
Pleurotaenium truncatum var. *mauritianum* Ir.-Mar.
62
Pleurotaenium verrucosum (Bail.) Lund.
20, 21, 74

=*P. trochiscum* var. *tuberculatum* G.M. Sm.
21, 43, 45, 59, 60, 62, 74, 100
Pleurotaenium verrucosum f. *villosum* (Ir.-Mar.) Croasdale
=*P. trochiscum* var. *tuberculatum* f. *villosum* Ir.-Mar.
60
Pleurotaenium verrucosum var. *bulbosum* Krieger
74
Pleurotaenium verrucosum var. *constrictum* Ir.-Mar.
74
Pleurotaenium spp.
20, 31, 39, 95, 124
Sphaerozosma aubertianum W. West
=*S. aubertianum* var. *archeri* (Gutw.) W. & G.S. West
59, 60, 97
Sphaerozosma vertebratum (Bréb.) Ralfs
97
Sphaerozosma vertebratum var. *latius* W. & G.S. West
63, 73
Sphaerozosma vertebratum var. *punctulatum* W. & G.S. West
20
=*S. punctatum* W. & G.S. West
43, 121
Sphaerozosma wallichii Jacobsen
92
Sphaerozosma spp.
20, 23, 29, 124, 126
Spinoclosterium cuspidatum (Bail. ex Ralfs) Hirano
20
=*Closterium cuspidatum* Bail. ex Ralfs
5, 57, 60, 61, 64
=*S. curvatum* var. *spinosum* Prescott
47
Spinocosmarium quadridens (Wood) Prescott & Scott
20, 60, 63
=*Arthrodesmus quadridens* Wood
21, 43, 47, 51, 74, 99, 100, 117, 124
Spinocosmarium quadridens f. *aspinosum* Ir.-Mar.
63
Spondylosium ellipticum W. & G.S. West
63
Spondylosium luetkemuelleri Grönbl.
=*S. moniliferum* Lund.
43, 47, 51, 59, 60, 63, 73
Spondylosium planum (Wolle) W. & G.S. West
5, 20, 21, 27, 28, 29, 43, 47, 51, 59, 60, 63, 73, 74, 76, 93, 97, 98, 99, 100, 110, 112, 124, 125, 126
Spondylosium pulchellum Archer
5, 20, 21, 45, 47, 51, 60, 63
Spondylosium pulchellum var. *bambusinoides* (Wittr.) Lund.
63
Spondylosium pulchrum (Bail.) Archer
5, 9, 20, 21, 43, 45, 47, 51, 60, 63, 74, 100, 121
Spondylosium pulchrum var. *constrictum* (Wolle) W. & G.S. West
=*S. pulchrum* var. *effringum* Ir.-Mar.
60, 63
Spondylosium rectangulare (Wolle) W. & G.S. West
47
Spondylosium secedens (De Bary) Archer
20, 21, 43, 54, 59, 63, 73, 74
=*Sphaerozosma secedens* De Bary
124
Spondylosium tetragonum W. West
51, 60, 63
Spondylosium sp.
20
Staurastrum aculeatum (Ehrenb.) Menegh. ex Ralfs
43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 100, 124, 129
Staurastrum affine W. & G.S. West
43, 54, 68, 69, 73, 100, 121
Staurastrum alternans (Bréb.) Ralfs
20, 21, 40, 92, 96, 97, 99, 100, 110, 111, 112, 117, 121, 124, 125, 126, 129
=*S. tricorne* (Bréb.) Ralfs
58, 60, 68
Staurastrum americanum f. *triradiata* (G.M. Sm.) Prescott, Vinyard & Bicudo
=*S. americanum* var. *triradiata* G.M. Sm.
47, 58
Staurastrum americanum var. *longiradiatum* G.M. Sm.
100
Staurastrum anatinum Cooke & Wills
1, 5, 20, 21, 29, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 76, 87, 88, 94, 97, 98, 99, 118, 124, 125
Staurastrum anatinum f. *curtum* (G.M. Sm.) Brook
20
=*S. anatinum* var. *curtum* G.M. Sm.
21, 43, 52, 54, 58, 60, 68, 69, 73, 74, 92, 94
Staurastrum anatinum f. *denticulatum* (G.M. Sm.) Brook
=*S. anatinum* var. *denticulatum* G.M. Sm.
54
Staurastrum anatinum f. *longibrachiatum* (W. & G.S. West) Brook
20, 27, 28
=*S. anatinum* var. *longibrachiatum* W. & G.S. West
1, 5, 21, 29, 43, 52, 58, 60, 68, 69, 73, 74, 88, 98, 99, 100, 124
Staurastrum anatinum f. *parvum* (W. West) Prescott, Vinyard & Bicudo
20
=*S. paradoxum* f. *parvum* W. West
21 (var. *parvum*), 24, 25 (var. *parvum*), 29 (var. *parvum*), 43, 52, 58, 60, 68, 73, 74, 88 (var. *parvum*), 92 (var. *parvum*), 99 (var. *parvum*), 100, 116 (var. *parvum*), 124 (var. *parvum*)
Staurastrum anatinum var. *controversum* (Bréb.) Brook
=*S. controversum* Bréb.
40, 43, 47, 58, 60, 68, 73, 100

Staurastrum anatinum var. *lagerheimii* (Schmidle) W. & G.S. West
20, 21
Staurastrum anatinum var. *nodulosum* (W. West) Prescott
20
=*S. paradoxum* var. *nodulosum* W. West
21
Staurastrum anatinum var. *truncatum* W. West
20, 21, 29, 43, 52, 54, 58, 60, 68, 69, 73, 74, 98, 99, 100, 124
Staurastrum anchora W. & G.S. West
68, 69, 92
Staurastrum angulatum var. *planctonicum* W. & G.S. West
21
Staurastrum ankyroides Wolle
5, 20, 47, 58, 60, 69, 82, 87
Staurastrum ankyroides var. *hexacerum* Wolle
20
Staurastrum ankyroides var. *pentacladum* G.M. Sm.
20, 21, 29, 43, 47, 58, 60, 68, 74, 98, 99, 100, 124
Staurastrum aphis Ir.-Mar.
60, 68, 69, 74
Staurastrum arachne Ralfs ex Ralfs
20, 21, 43, 47, 52, 58, 60, 68, 69, 74, 100
Staurastrum arachne f. *minus* Ir.-Mar.
68
Staurastrum arachne var. *curvatum* W. & G.S. West
68
Staurastrum arachne var. *gyrans* (Johnson) Scott & Grönbl.
=*S. gyrans* Johnson
43
Staurastrum arachne var. *gyrans* f. *quadratum* (Ir.-Mar.) Prescott, Vinyard & Bicudo
=*S. gyrans* f. *quadratum* Ir.-Mar.
43
Staurastrum arctiscon (Ehrenb. ex Ralfs) Lund.
1, 5, 20, 21, 29, 43, 47, 52, 54, 58, 60, 68, 69, 74, 82, 87, 88, 92, 94, 97, 98, 99, 124
Staurastrum arctiscon var. *glabrum* W. & G.S. West
5, 20, 21, 25, 26, 43, 47, 52, 58, 60, 68, 69, 74, 88, 92, 94
Staurastrum arctiscon var. *truncatum* Ir.-Mar.
5, 20, 21, 43, 47, 60, 68, 69, 74, 100
Staurastrum arcuatum Nordst.
43, 60, 68, 74
Staurastrum arcuatum var. *pseudopisciforme* (Eichl. & Gutw.) W. & G.S. West
=*S. pseudopisciforme* Eichl. & Gutw.
43, 68
Staurastrum aspinosum Wolle
60
Staurastrum avicula Bréb. ex Ralfs
20, 29, 54, 58, 60, 68, 69, 99, 124
?*Staurastrum avicula* f. *biradiatum* Brunel
21
Staurastrum avicula var. *inerme* Ir.-Mar.
52, 68
Staurastrum avicula var. *subarcuatum* (Wolle) W. & G.S. West
20, 21, 27, 28, 29, 43, 47, 52, 58, 60, 68, 69, 73, 74, 98, 99, 116, 121, 124
Staurastrum avicula var. *subarcuatum* f. *quadratum* Ir.-Mar.
68, 74
Staurastrum bacillare var. *obesum* Lund.
20, 21, 43, 47, 52, 54, 60, 68, 124, 125
Staurastrum bicorne Hauptfleisch
54, 68, 69, 74, 92
Staurastrum bicoronatum var. *simplicius* W. & G.S. West
47, 68
Staurastrum bieneanum Rabenh.
68, 89, 90, 129
Staurastrum bieneanum var. *ellipticum* Wille
68
Staurastrum bioculatum Taylor
20, 47, 58, 60, 69, 74
Staurastrum boreale W. & G.S. West
94
Staurastrum boreale var. *robustum* Messik.
68
Staurastrum botrophilum Wolle
47, 58, 60
Staurastrum brachiatum Ralfs
5, 20, 21, 29, 43, 47, 54, 58, 60, 68, 69, 73, 74, 93, 97, 98, 99, 100, 117, 124
Staurastrum brachiatum var. *incisum* G.M. Sm.
20
Staurastrum brasiliense Nordst.
69
Staurastrum brasiliense var. *lundellii* W. & G.S. West
5, 20, 21, 47, 54, 58, 60, 68, 69, 74, 100
=*S. brasiliense* var. *lundellii* f. *majus* Ir.-Mar.
74
Staurastrum brebissonii Archer
20
=*S. pilosum* Bréb.
43, 52, 58, 60, 68, 69, 87, 97
Staurastrum brebissonii var. *brasiliense* Grönbl.
52, 58, 68, 73
Staurastrum brebissonii var. *brevispinum* W. West
20, 21, 43, 58, 60, 69, 98, 100
Staurastrum bullardii G.M. Sm.
5, 20, 58, 74
Staurastrum caronense Ir.-Mar.
52, 68, 69
Staurastrum cerastes Lund.
5, 20, 21, 43, 47, 54, 58, 60, 68, 69, 73, 74, 100, 124
Staurastrum cerastes var. *triradiatum* G.M. Sm.
47, 58
Staurastrum cingulum (W. & G.S. West) G.M. Sm.
105

Staurastrum cingulum var. *obesum* G.M. Sm.
47
Staurastrum cingulum var. *ornatum* Ir.-Mar.
52, 68, 74
Staurastrum claviferum W. & G.S. West
20, 52, 68, 74
=*S. breviaculeatum* G.M. Sm.
6, 21, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 100, 124
Staurastrum clevei (Wittr.) Roy & Biss.
20, 21, 47, 54, 60, 74, 99, 117, 124
Staurastrum coderrii Ir.-Mar.
60, 68, 74
Staurastrum commissurale var. *crassum* Nordst.
100
Staurastrum compactum Whelden
129
Staurastrum comptum Wolle
47
Staurastrum comptum var. *majus* Wolle
=*S comptum* Wolle sensu Ir.-Mar.
60
Staurastrum cornutum Archer
20, 21, 43, 54, 60, 68, 69, 73, 74, 92, 100, 124, 125
Staurastrum cornutum f. *biradiatum* Ir.-Mar.
68, 69
Staurastrum coronulatum var. *quebecense* Ir.-Mar.
60, 68, 74
Staurastrum cosmarioides Nordst.
43, 47, 58, 60, 93
Staurastrum cosmarioides var. *minus* Ir.-Mar.
68
Staurastrum crenulatum (Näg.) Delp.
20, 43, 47, 58, 60, 68, 69, 74, 100, 124, 129
Staurastrum cristatum (Näg.) Archer
129
Staurastrum cruciatum Wolle
69
Staurastrum cyrtocerum (Bréb.) Ralfs
21, 43, 58, 60, 68, 69, 73, 74, 92, 96, 100, 129
Staurastrum denticulatum (Näg.) Archer
20
Staurastrum diacanthum Lemaire
=*S. acestrophorum* W. & G.S. West
60
Staurastrum diacanthum var. *glabrius* f. *quadratum* (Ir.-Mar.) Prescott, Vinyard & Bicudo
=*S. acestrophorum* var. *glabrius* f. *quadratum* Ir.-Mar.
60, 74
Staurastrum dilatatum (Ehrenb.) Ralfs
20, 21, 29, 43, 47, 52, 58, 60, 68, 69, 73, 74 (aussi sous *S. dilatatum* Wolle), 92, 93, 94, 97, 99, 100, 124, 129
Staurastrum dilatatum var. *hibernicum* W. & G.S. West
69
Staurastrum disputatum var. *extensum* (Borge) W. & G.S. West
68, 69, 74
Staurastrum distentum Wolle
20, 21, 58, 60, 68, 74 (*S. dilatatum* Wolle)
Staurastrum echinatum Bréb.
60
Staurastrum echinatum var. *sicaeferum* Ir.-Mar.
60
Staurastrum elongatum Barker
5, 20, 47, 52, 60, 68, 74, 100
Staurastrum elongatum f. *pentagonum* Ir.-Mar.
60
Staurastrum elongatum f. *quadratum* (Ir.-Mar.) Prescott
=*S. elongatum* var. *quadratum* Ir.-Mar.
43
Staurastrum elongatum f. *tetragonum* (Wolle) Ir.-Mar.
60, 73, 74
=*S. elongatum* var. *tetragonum* Wolle
47, 52
Staurastrum erasum Bréb.
52, 68, 69, 74, 97
Staurastrum excavatum W. & G.S. West
69
Staurastrum filiferum Ralfs
96
Staurastrum floriferum W. & G.S. West
94, 97
Staurastrum forficulatum Lund.
20, 21, 124
Staurastrum forficulatum var. *enoplon* W. West
47, 58, 60
Staurastrum forficulatum var. *evolutum* Prescott
=*S. forficulatum* forma Ir.-Mar.
43, 60, 68, 73, 74
Staurastrum franconicum Reinsch
58, 60, 69
=*S. franconicum* forma Ir.-Mar.
43, 68
Staurastrum frangens Ir.-Mar.
60, 68, 69, 74
Staurastrum furcatum (Ehrenb. ex Ralfs) Bréb.
20, 21, 43, 47, 52, 58, 60, 68, 69, 73, 74, 99, 117, 124, 125, 129
Staurastrum furcatum f. *elegantius* Ir.-Mar.
20, 21, 43, 47, 52, 58, 60, 68, 73, 74, 124
Staurastrum furcatum f. *ellipticum* Ir.-Mar.
60
Staurastrum furcatum var. *pisciforme* (Turn.) Ir.-Mar.
20, 43, 47, 52, 58, 60, 68, 74, 99, 117, 124
Staurastrum furcatum var. *spinatum* Ir.-Mar.
60, 69
Staurastrum furcatum var. *subsenarium* W. & G.S. West
43, 47, 60

Staurastrum furcigerum (Bréb. ex Ralfs) Bréb.
20. 21. 24. 25. 43. 47. 52. 54. 58. 60. 68. 69. 73. 74. 88. 92. 94. 97. 124. 125. 129
=*S. furcigerum* forma Le Gallo & Whelden
92
Staurastrum furcigerum f. *eustephanum* (Ehrenb.) Nordst.
5. 43. 47. 52. 58. 60. 68. 69. 73. 92. 93
Staurastrum furcigerum var. *armigerum* (Bréb.) Nordst.
43. 47. 52. 58. 60. 68. 69. 74. 93
Staurastrum furcigerum var. *reductum* W. & G.S. West
92
Staurastrum gatniense W. & G.S. West
20
Staurastrum geminatum Nordst.
20
Staurastrum geminatum var. *longispinum* Printz
20. 47. 52. 60. 68. 74
Staurastrum gladiosum Turn.
20. 21. 24. 25. 40. 43. 47. 52. 54. 60. 68. 69. 74. 88. 93. 100
Staurastrum gracile Ralfs ex Ralfs
20. 21. 29. 43. 47. 52. 54. 58. 60. 68. 69. 73. 82. 87. 88. 92. 97. 98. 99. 117. 121. 124. 129
Staurastrum gracile var. *nanum* Wille
20. 43. 47. 52. 54. 58. 60. 68. 69. 73. 74. 100
Staurastrum gracile var. *tenuissimum* Boldt
20. 21. 43. 60. 100
Staurastrum grallatorium Nordst.
47. 60. 68
Staurastrum grallatorium var. *forcipigerum* Lagerh.
6. 20. 21. 43. 47. 60. 69. 74
Staurastrum grallatorium var. *forcipigerum* f. *longispinum* Ir.-Mar.
60
Staurastrum granulosum (Ehrenb.) Ralfs
20. 21. 43. 47. 52. 54. 58. 60. 68. 73. 92. 121. 129
Staurastrum gratianum Ir.-Mar.
52. 68
Staurastrum haaboeliense Wille
20. 21. 124
Staurastrum habeebense Ir.-Mar.
55. 60. 68
Staurastrum hexacerum (Ehrenb.) Wittr.
20. 25. 26. 43. 58. 60. 68. 69. 73. 74. 88. 94. 97. 100. 121
Staurastrum hystrix Ralfs ex Ralfs
47. 60
Staurastrum hystrix var. *pannonicum* Lütk.
5
Staurastrum illusum G.S. West
68
=*S. alternans* Bréb. ex Ralfs
43. 47. 52. 54. 58. 60. 68. 69. 73. 74
Staurastrum illusum var. *majus* Ir.-Mar.
52. 58. 68. 69

Staurastrum incisum Wolle
47. 94
Staurastrum inconspicuum Nordst.
5. 20. 21. 29. 43. 47. 54. 58. 60. 68. 69. 74. 98. 99. 100. 124. 125. 129
Staurastrum inconspicuum var. *planctonicum* G.M. Sm.
20. 21
Staurastrum inflexum Bréb.
43. 47. 52. 54. 58. 60. 68. 69. 73. 74. 100. 124. 129
Staurastrum iotanum Wolle
20. 21. 43. 47. 52. 54. 58. 60. 68. 69. 73. 74. 94. 100. 129
Staurastrum johnsonii W. & G.S. West
1. 5. 20. 21. 27. 28. 29. 43. 47. 52. 54. 58. 60. 68. 73. 74. 76. 82. 87. 88. 92. 94. 98. 99. 100. 124
Staurastrum johnsonii var. *depauperatum* G.M. Sm.
20. 21. 43. 47. 54. 58. 60. 68. 73. 74
Staurastrum johnsonii var. *evolutum* Scott & Grönbl.
74
Staurastrum johnsonii var. *granulatum* Ir.-Mar.
68
Staurastrum junkianum Ir.-Mar.
68
Staurastrum labarrii Ir.-Mar.
20. 21. 60
Staurastrum laconiense W. & G.S. West
68
Staurastrum lacustre G.M. Sm.
5. 20. 29. 43. 47. 58. 60. 68. 97. 98. 99. 124
Staurastrum laeve Ralfs
20. 43
Staurastrum lapponicum (Schmidle) Grönbl.
20
Staurastrum leptacanthum Nordst.
5. 20. 21. 29. 43. 47. 58. 60. 68. 69. 99. 100. 124
Staurastrum leptocladum Nordst.
5. 20. 21. 27. 28. 43. 47. 52. 54. 58. 60. 68. 69. 74. 92. 97. 98. 100. 124
Staurastrum leptocladum var. *denticulatum* G.M. Sm.
20. 47. 58. 60
Staurastrum leptocladum var. *insigne* W. & G.S. West
20. 21. 74
Staurastrum leptocladum var. *sinuatum* Wolle
47. 60. 68. 74
Staurastrum leptocladum var. *sinuatum* f. *planum* G.M. Sm.
20. 43. 47. 60. 68. 69. 74
Staurastrum limneticum var. *canadense* Ir.-Mar.
43. 52. 68
Staurastrum longipes (Nordst.) Teil.
20
=*S. paradoxum* var. *longipes* Nordst.
21. 24. 25. 29. 47. 60. 68. 74. 88. 97. 99. 124
Staurastrum longipes var. *contractum* Teil.
20

Staurastrum longiradiatum W. & G.S. West
24, 25, 54, 68, 88
Staurastrum longiradiatum var. *mistassiniense* Ir.-Mar.
54, 68, 74
Staurastrum longispinum (Bail.) Archer
20, 21, 29, 47, 52, 58, 60, 68, 74, 99, 100, 117, 124
Staurastrum lunatum Ralfs
20, 21, 27, 28, 40, 43, 52, 54, 58, 60, 68, 69, 73, 74, 124, 129
Staurastrum lunatum var. *planctonicum* W. & G.S. West
20, 43, 69, 97, 129
Staurastrum maamense Archer
5, 20, 21, 43, 47, 52, 54, 58, 60, 68, 69, 74, 97
Staurastrum magnottae Scott & Grönbl.
=*S. maamense* f. *atypicum* Magnotta
69
Staurastrum manfeldtii Delp.
20, 43, 58, 60, 69, 73, 100
Staurastrum manfeldtii var. *annulatum* W. & G.S. West
47, 52, 60, 74 (var. *crenulatum* W. & G.S. West)
Staurastrum margaritaceum (Ehrenb.) Ralfs
20, 21, 43, 47, 52, 58, 60, 68, 69, 74, 92, 93, 97, 99, 100, 117, 124
Staurastrum margaritaceum var. *coronulatum* W. West
20, 21
Staurastrum mattawinii Ir.-Mar.
74
Staurastrum megacanthum Lund.
20, 21, 24, 25, 29, 43, 47, 54, 58, 60, 68, 69, 74, 88, 97, 98, 99, 100, 110, 112, 117, 124
Staurastrum megacanthum var. *scoticum* W. & G.S. West
20, 29, 52, 68, 74, 99, 124
Staurastrum meriani Reinsch
40, 43, 47, 60, 69, 92
Staurastrum micron W. & G.S. West
43, 52, 54, 58, 60, 68, 73, 74
Staurastrum micron f. *biradiatum* Ir.-Mar.
43
Staurastrum minnesotense Wolle
20, 29, 43, 47, 58, 68, 69, 98, 99, 124
Staurastrum minnesotense var. *brunelii* Ir.-Mar.
43
Staurastrum minnesotense var. *depauperatum* Ir.-Mar.
20, 43, 100
Staurastrum minnesotense var. *majusculum* (Wolle) Scott & Grönbl.
20
=*S. majusculum* Wolle
21, 43, 58, 60, 68, 100
Staurastrum minutissimum (Auser. ?ex Rabenh.) Reinsch
69
Staurastrum minutum (Näg.) Coll.
40
Staurastrum monticulosum Bréb. ex Ralfs
47, 52, 60, 68, 74, 93, 124
Staurastrum monticulosum f. *arseni* Ir.-Mar.
43
Staurastrum monticulosum f. *groenlandicum* Grönbl.
60
Staurastrum monticulosum var. *inerme* Ir.-Mar.
60, 68
Staurastrum monticulosum var. *irenee-mariae* Graffius
=*S. aciculiferum* (W. West) Andersson
43, 47, 60
Staurastrum muricatum (Bréb.) Ralfs
52, 58, 60, 68, 69, 92
Staurastrum muticum (Bréb.) Ralfs
5, 20, 21, 24, 25, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 76, 88, 90, 92, 93, 96, 100, 129
Staurastrum muticum f. *minus* Rabenh.
68
Staurastrum natator W. West
20, 21, 43, 52, 54, 58, 60, 68, 82, 87, 100, 124, 125
Staurastrum natator var. *crassum* W. & G.S. West
20, 21, 52, 54, 68
Staurastrum neglectum G.S. West
20, 47, 92, 129
Staurastrum novae-caesareae Wolle
47, 60, 69
Staurastrum novae-terrae Taylor
47, 60, 69, 74
Staurastrum novae-terrae var. *taylorii* Ir.-Mar.
60, 69
Staurastrum novae-terrae var. *taylorii* f. *evolutum* Ir.-Mar.
60, 69
Staurastrum ophiura Lund.
5, 20, 21, 29, 43, 47, 52, 54, 58, 60, 68, 69, 74, 87, 97, 98, 99, 100, 117, 124
Staurastrum ophiura var. *cambricum* (Lund.) W. & G.S. West
47, 58, 60, 68
Staurastrum orbiculare (Ehrenb.) Ralfs
4, 43, 52, 54, 58, 60, 68, 69, 73, 74, 92, 96, 97, 100, 129
Staurastrum orbiculare var. *depressum* Roy & Biss.
60, 68, 69, 74, 94, 97
Staurastrum orbiculare var. *extensum* Nordst.
20
Staurastrum orbiculare var. *hibernicum* W. & G.S. West
43, 54, 58, 60, 68, 73, 74
Staurastrum orbiculare var. *minus* Reinsch
69
Staurastrum orbiculare var. *ralfsii* W. & G.S. West
47, 68, 69, 92, 94, 129
Staurastrum ornithopodum W. & G.S. West
47, 54, 60

Staurastrum palmatum Ir.-Mar.
60, 74
Staurastrum paradoxum Meyen ex Ralfs
1, 21, 24, 25, 29, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 82, 87, 88, 92, 94, 97, 98, 99, 100, 105, 109, 110, 111, 112, 117, 121, 124, 125
=*S. anatinum* f. *paradoxum* (Meyen) Brook
27, 28
Staurastrum pentacerum (Wolle) G.M. Sm.
5, 20, 21, 27, 28, 29, 43, 47, 52, 54, 58, 60, 68, 69, 74, 76, 98, 99, 100, 109, 110, 111, 112, 121, 124, 125
Staurastrum pentacerum var. *hexacerum* Ir.-Mar.
68, 74
Staurastrum pentacerum var. *tetracerum* (Wolle) G.M. Sm.
20, 21, 27, 28, 43, 54, 58, 60, 68, 100
Staurastrum pilosellum W. & G.S. West
47
Staurastrum pingue Teil.
27, 28
Staurastrum pingue var. *evolutum* (W. & G.S. West) Prescott
=*S. paradoxum* var. *evolutum* (W. & G.S. West) W. & G.S. West
47
Staurastrum planctonicum Teil.
124
Staurastrum polymorphum Bréb. ex Ralfs
4, 20, 21, 24, 25, 29, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 88, 92, 93, 97, 99, 100, 121, 124, 129
Staurastrum polymorphum var. *pusillum* W. West
27, 28, 47
Staurastrum polymorphum var. *simplex* W. & G.S. West
47, 52, 60, 68, 69, 74
Staurastrum polytrichum (Perty) Rabenh.
92, 97
Staurastrum proboscideum (Bréb.) Archer
40, 129
Staurastrum protectum var. *planctonicum* G.M. Sm.
20, 21, 29, 43, 47, 54, 58, 60, 68, 69, 74, 98, 99, 100, 124
Staurastrum pseudobengalicum W. & G.S. West
27, 28
Staurastrum pseudopelagicum W. & G.S. West
5, 60, 68, 97
Staurastrum pseudosebaldi Wille
43, 47, 58, 60, 68, 69, 73, 98, 100
Staurastrum pseudotetracerum (Nordst.) W. & G.S. West
20, 21
Staurastrum punctulatum (Bréb.) Ralfs
5, 20, 21, 40, 43, 47, 52, 54, 58, 60, 68, 90, 92, 93, 97, 100, 121, 124, 129
Staurastrum punctulatum var. *kjellmani* Wille
47, 93
Staurastrum punctulatum var. *pygmaeum* (Bréb.) W. & G.S. West
43, 47, 60, 92, 129
Staurastrum punctulatum var. *subproductum* W. & G.S. West
90, 92
Staurastrum pyramidatum W. West
20, 21, 43, 47, 52, 60, 68, 74, 92
Staurastrum quadrangulare (Bréb.) Ralfs
20, 21, 69, 94, 100
Staurastrum quadrangulare var. *armatum* W. & G.S. West
20, 21, 43, 52, 58, 60, 68, 94
Staurastrum quadrispinatum Turn.
20, 47, 60, 94
Staurastrum quebecense Ir.-Mar.
20, 21, 43, 47, 54, 60, 68, 69, 74, 92, 100
Staurastrum quebecense f. *biradiatum* Ir.-Mar.
68
Staurastrum ravenellii var. *spinulosum* Ir.-Mar.
20, 21, 43, 47, 52, 58, 60, 68, 69, 73, 100
Staurastrum retusum Turn.
43, 58, 60, 100
Staurastrum rhabdophorum Nordst.
92
Staurastrum rotula Nordst.
5, 20, 21, 43, 47, 54, 58, 60, 68, 69, 73, 74, 96, 100
Staurastrum rotundatum Turn.
58, 74
Staurastrum rugosum Ir.-Mar.
43, 47, 52, 54, 60, 68, 73, 74
Staurastrum rugosum var. *biradiatum* Ir.-Mar.
52, 54, 60, 68
Staurastrum rugulosum Bréb. ex Ralfs
47, 54, 60
Staurastrum saxonicum Bulnh.
47, 58, 60, 96
Staurastrum sebaldi Reinsch
43, 52, 58, 68, 69, 73, 74, 87, 124, 125
Staurastrum sebaldi var. *ornatum* Nordst.
20, 21, 43, 47, 52, 58, 60, 68, 69, 73, 94, 100
Staurastrum sebaldi var. *ornatum* f. *tetragonum* Ir.-Mar.
58
Staurastrum sebaldi var. *productum* W. & G.S. West
68
Staurastrum senarium (Ehrenb.) Ralfs
60
Staurastrum setigerum Cleve
5, 20, 21, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 92, 93, 100, 109, 124, 129
Staurastrum setigerum var. *occidentale* W. & G.S. West
47, 58, 60
Staurastrum setigerum var. *pectinatum* W. & G.S. West
20, 21, 43, 52, 68, 69, 92
Staurastrum sexcostatum var. *productum* W. West
43, 69, 73
Staurastrum simonyi Heimerl
20, 21, 43, 47, 58, 60, 68, 69, 73, 74, 92, 100, 124, 125

Staurastrum spiculosum (G.M. Sm.) Scott & Grönbl.
20
=*S. spiculiferum* G.M. Sm.
21, 43, 47, 58, 60, 68, 69, 99, 100, 117, 124, 125, 126
Staurastrum spiniferum W. West
60, 74
Staurastrum spiniferum var. *quadratum* Ir.-Mar.
60
Staurastrum spongiosum Bréb. ex Ralfs
43, 52, 54, 58, 60, 68, 69, 74, 92, 93, 96
Staurastrum spongiosum var. *perbifidum* W. West
43, 47, 52, 60, 68, 93
Staurastrum spongiosum var. *perbifidum* f. *spinosum* Ir.-Mar.
43, 52, 68
Staurastrum stipes Ir.-Mar.
52, 60, 68
Staurastrum striolatum (Näg.) Archer
60
Staurastrum striolatum var. *divergens* W. & G.S. West
69
Staurastrum striolatum var. *divergens* f. *majus* Ir.-Mar.
73
Staurastrum subavicula f. *tyrolense* (Schmidle) Prescott, Vinyard & Bicudo
=*S. subavicula* var. *tyrolense* Schmidle
43, 60
Staurastrum subcornutum var. *quebecense* Ir.-Mar.
68
Staurastrum subcruciatum Cooke & Wills
20, 29, 47, 58, 60, 92, 94, 99, 124
Staurastrum subcruciatum var. *trispinatum* Ir.-Mar.
58, 60, 68
Staurastrum subgracillimum W. & G.S. West
20, 21, 60, 68, 69, 74
Staurastrum subgrande Borge
68, 74
Staurastrum subgrande var. *minus* G.M. Sm.
20, 21
Staurastrum sublaevispinum W. & G.S. West
20, 21, 43, 47, 54, 60, 69, 74
Staurastrum sublongipes G.M. Sm.
68, 74
Staurastrum subnudibrachiatum W. & G.S. West
20, 21, 29, 47, 58, 60, 74, 99, 124
Staurastrum subnudibrachiatum var. *incisum* G.M. Sm.
20, 21
Staurastrum subnudibrachiatum var. *latispinum* Ir.-Mar.
68
Staurastrum suborbiculare W. & G.S. West
92
Staurastrum subscabrum Nordst.
43, 52, 60, 68, 69, 74, 100
Staurastrum subscolopacinum W. & G.S. West
52, 68
Staurastrum subteliferum Roy & Biss.
20, 21
Staurastrum teliferum Ralfs
20, 29, 43, 47, 52, 58, 60, 68, 92, 99, 100, 124
Staurastrum tenuissimum W. & G.S. West
69
Staurastrum tetracerum (Kütz.) Ralfs
20, 21, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 92, 94, 99, 100, 117, 124, 125
Staurastrum tetracerum f. *tetragonum* W. & G.S. West
60, 74
Staurastrum tetracerum f. *trigonum* Lund.
20, 21, 47, 58, 60
=*S. tetracerum* var. *trigonum* Lund.
54, 68, 92
Staurastrum tetracerum var. *evolutum* W. & G.S. West
47
Staurastrum tetracerum var. *evolutum* f. *minus* Ir.-Mar.
68
Staurastrum tohopekaligense Wolle
20, 21, 47, 60, 68, 69, 98
Staurastrum tohopekaligense var. *brevispinum* G.M. Sm.
20, 21, 43, 60, 68, 69
=*S. tohopekaligense* var. *trifurcatum* W. & G.S. West
29, 98, 99, 124
Staurastrum tohopekaligense var. *nonanum* (Turn.) Schmidle
43, 47, 58, 69
Staurastrum trifidum Nordst.
5, 68, 69, 124
Staurastrum trifidum var. *inflexum* W. & G.S. West
20, 21, 47, 52, 58, 60, 68, 69, 73, 124
Staurastrum trihastiferum G.M. Sm.
20, 21, 60
Staurastrum trihedrale Wolle
47, 52, 60, 68, 69, 74
Staurastrum triserrulum Ir.-Mar.
52, 68, 74
Staurastrum triserrulum f. *minus* Ir.-Mar.
74
Staurastrum triundulatum var. *floridense* Scott & Grönbl.
74
Staurastrum tumidum (Bréb.) Ralfs
20, 43, 47, 52, 58, 60, 68, 74, 100
Staurastrum turgescens var. *canadense* Ir.-Mar.
68
Staurastrum urinator G.M. Sm.
20, 21
Staurastrum varians var. *badense* Schmidle
129

Staurastrum vestitum Ralfs
20, 21, 29, 43, 47, 52, 54, 58, 60, 68, 69, 74, 99, 100, 124, 129
Staurastrum vestitum var. *subanatinum* W. & G.S. West
20, 21, 29, 43, 58, 68, 74, 98, 99, 124
Staurastrum vestitum var. *tortum* W. & G.S. West
43
Staurastrum wolleanum var. *heptacanthum* Ir.-Mar.
68
Staurastrum wolleanum var. *kissimense* Wolle
20, 21, 60, 68
Staurastrum xiphidiophorum var. *simplex* Wolle
68
Staurastrum spp.
1, 20, 22, 23, 24, 29, 39, 76, 78, 82, 87, 92, 95, 99, 100, 116, 117, 118, 124, 125, 126
Staurodesmus aristiferus (Ralfs) Thom.
=*Staurastrum aristiferum* Ralfs
24, 25, 27, 28, 29, 47, 88, 99, 124
=*Staurastrum aristiferum* var. *prescottii* Ir.-Mar.
60
Staurodesmus aversus (Lund.) Lillier.
=*Staurastrum aversum* Lund.
29, 60, 98, 99, 124
Staurodesmus brevispina (Bréb. ex Ralfs) Croasdale
5
=*Staurastrum brevispina* (Bréb. ex Ralfs) Ralfs
6, 20, 21, 29, 40, 43, 47, 54, 58, 68, 74, 90, 92, 94, 98, 99, 110, 112, 124, 129
=*Staurastrum brevispina* f. *majus* W. & G.S. West
20, 21, 29, 43, 54, 60, 68, 69, 99, 124
Staurodesmus brevispina var. *obversus* (W. & G.S. West) Croasdale
=*Staurastrum brevispina* var. *obversum* W. & G.S. West
74
=*Staurastrum brevispina* var. *obversum* f. *minus* Ir.-Mar.
74
Staurodesmus bulnheimii (Racib.) Brook
=*Arthrodesmus bulnheimii* Racib.
43, 59, 60, 73, 74, 100, 124, 125
Staurodesmus bulnheimii var. *subincus* (W. & G.S. West) Thom.
=*Arthrodesmus bulnheimii* var. *subincus* W. & G.S. West
20, 21, 43, 47, 59, 60, 63, 74, 124, 125
Staurodesmus calyxoides (Wolle) Croasdale
=*Staurastrum calyxoides* Wolle
47, 60, 73
Staurodesmus calyxoides var. *incurvus* (Ir.-Mar.) Teil.
=*Staurastrum calyxoides* var. *incurvum* Ir.-Mar.
60, 73
Staurodesmus clepsydra (Nordst.) Teil.
=*Staurastrum clepsydra* Nordst.
129
Staurodesmus connatus (Lund.) Thom.
=*Staurastrum connatum* (Lund.) Roy & Biss.
20, 21, 43, 52, 58, 68, 69, 74, 100, 124
Staurodesmus conspicuus (W. & G.S. West) Teil.
=*Staurastrum conspicuum* W. & G.S. West sensu Ir-Mar.
20, 21, 43, 47, 52, 60, 69
Staurodesmus convergens (Ehrenb. ex Ralfs) Lillier.
=*Arthrodesmus convergens* Ehrenb. ex Ralfs
4, 6, 20, 21, 43, 47, 51, 59, 60, 63, 73, 93, 97, 98, 100, 124
=*Arthrodesmus convergens* var. *deplanatus* (Defl.) Laporte
47, 60
Staurodesmus convergens var. *ralfsii* Teil.
=*Arthrodesmus convergens* var. *inermis* Jacobsen
47, 60
Staurodesmus convergens var. *pumilus* (Nordst.) Teil.
=*Arthrodesmus convergens* var. *exaltatus* (Cederg.) Laporte
60
Staurodesmus convergens var. *wollei* (Ir.-Mar.) Teil.
=*Arthrodesmus convergens* var. *wollei* Ir.-Mar.
60
Staurodesmus corniculatus (Lund.) Teil.
=*Staurastrum corniculatum* var. *spinigerum* W. West
43, 68, 74
Staurodesmus crassus (W. & G.S. West) Lillier.
=*Arthrodesmus crassus* W. & G.S. West
29, 99, 124
Staurodesmus curvatus var. *obesus* (W. & G.S. West) Teil.
=*Arthrodesmus convergens* var. *obesus* W. & G.S. West
51, 63
Staurodesmus cuspidatus (Bréb. ex Ralfs) Teil.
=*Arthrodesmus constrictus* G.M. Sm.
20, 21
=*S. cuspidatus* subsp. *constrictus* (G.M. Sm.) Teil.
5 (var. *constrictus*)
=*Staurastrum cuspidatum* (Bréb. ex Ralfs) Ralfs
20, 21, 29, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 92, 94, 97, 98, 99, 124, 129
=*Staurastrum cuspidatum* var. *divergens* Nordst.
20, 21, 29, 43, 47, 58, 60, 68, 69, 74, 98, 99, 100, 124
=*S. cuspidatus* var. *divergens* (Nordst.) Bourrelly
5
Staurodesmus cuspidatus var. *curvatus* (W. West) Teil.
=*Staurastrum curvatum* W. West
20, 21, 27, 28, 29, 68, 69, 124
=*Staurastrum curvatum* var. *elongatum* G.M. Sm.
20, 27, 28, 68, 69
=?*Staurastrum curvatum* var. *minus* Brunel
21
=*Staurastrum cuspidatum* var. *canadense* G.M. Sm.
47, 58, 60, 68, 69, 74, 100

Staurodesmus dejectus (Bréb. ex Ralfs) Teil.
=*Staurastrum dejectum* (Bréb. ex Ralfs) Ralfs
20, 21, 27, 28, 29, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 92, 93, 94, 97, 99, 100, 117, 124, 125, 126
=*Staurastrum dejectum* f. *majus* W. & G.S. West
27, 28, 29, 58, 60, 99, 124
Staurodesmus dejectus var. *apiculatus* (Bréb.) Teil.
=*Staurastrum dejectum* var. *apiculatum* (Bréb.) Lund.
20
=*Staurastrum apiculatum* Bréb.
21, 29, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 92, 94, 98, 99, 124, 129
Staurodesmus dickiei (Ralfs) Lillier.
=*Staurastrum dickiei* Ralfs
24, 25, 43, 47, 52, 54, 58, 60, 68, 69, 73, 74, 88, 92, 93, 94
Staurodesmus dickiei var. *circularis* (Turn.) Croasdale
=*Staurastrum dickiei* var. *circulare* Turn.
20, 43, 47, 52, 54, 58, 60, 68, 69, 92, 93, 94, 97
Staurodesmus dickiei var. *curvispinus* (Ir.-Mar.) Teil.
=*Staurastrum curvispinum* Ir.-Mar.
52, 68
Staurodesmus dickiei var. *maximus* (W. & G.S. West) Thomasson
=*Staurastrum dickiei* var. *maximum* W. & G.S. West
43, 52, 54, 58, 68, 69, 73, 94
Staurodesmus dickiei var. *rhomboideus* (W. & G.S. West) Lillier.
=*Staurastrum dickiei* var. *rhomboideum* W. & G.S. West
20, 21, 43, 47, 58, 60, 68, 69, 74, 92, 109
=*Staurastrum dickiei* var. *rhomboideum* f. *depressum* Ir.-Mar.
43, 54, 58, 69
Staurodesmus extensus (Borge) Teil.
5
=*Arthrodesmus extensus* (Borge) Hirano
20
=*Arthrodesmus incus* var. *extensus* Andersson
21, 27, 28, 29, 43, 51, 53, 59, 60, 63, 74, 76, 77 (*Staurodesmus incus* var. *extensus*), 99, 100, 117, 124, 125, 126
=*Arthrodesmus ralfsii* var. *extensus* Ir.-Mar.
60
Staurodesmus extensus var. *joshuae* (Gutw.) Teil.
=*Arthrodesmus incus* var. *praelongus* G.M. Sm.
63, 92
Staurodesmus glaber (Ehrenb. ex Ralfs) Teil.
=*Staurastrum glabrum* (Ehrenb.) Ralfs
43, 69, 92, 124, 129
Staurodesmus grandis (Bulnh.) Teil.
=*Staurastrum grande* Bulnh.
20, 21, 58, 60, 68, 69, 73, 97
=*Staurastrum brevispinum* var. *inerme* Wille
47, 58, 60
Staurodesmus grandis var. *parvus* (W. & G.S. West) Teil.
=*Staurastrum grande* var. *parvum* W. & G.S. West
20, 21, 24, 25, 43, 47, 52, 58, 60, 68, 69, 73, 88, 93, 96, 100
Staurodesmus grandis var. *rotundatus* (W. & G.S. West) Teil.
=*Staurastrum grande* var. *rotundatum* W. & G.S. West
43, 52, 58, 60, 68, 69, 73, 74, 97, 124
=*Staurastrum grande* var. *rotundatum* f. *majus* Ir.-Mar.
60
Staurodesmus incus (Bréb. ex Ralfs) Teil.
77
=*Arthrodesmus incus* (Bréb. ex Ralfs) Hass. ex Ralfs
20, 21, 27, 28, 29, 39, 42, 51, 59, 63, 76, 97, 99, 100, 106, 109, 110, 111, 112, 117, 118, 124, 125, 126
Staurodesmus incus f. *minus* (W. & G.S. West) Teil.
=*Arthrodesmus incus* f. *minus* W. & G.S. West
29, 47, 99, 124
Staurodesmus incus var. *ralfsii* (W. West) Teil.
=*Arthrodesmus ralfsii* W. West
20, 21, 29, 43, 47, 53, 59, 63, 74, 76, 99, 109, 110, 112, 117, 124, 129
=*Arthrodesmus incus* var. *ralfsii* W. & G.S. West
29, 124
=*Arthrodesmus incus* var. *ralfsii* f. *latiuscula* W. & G.S. West
124
=?*Arthrodesmus ralfsii* f. *latiuscula* W. & G.S. West
21, 29, 43, 98, 99, 110, 112, 117, 124
Staurodesmus indentatus (W. & G.S. West) Teil.
=*Arthrodesmus incus* var. *indentatus* W. & G.S. West
24, 25, 29, 88, 99, 100, 124
Staurodesmus mamillatus (Nordst.) Teil.
=*Staurastrum cuspidatum* var. *delpontei* Ir.-Mar.
60
Staurodesmus mamillatus var. *maximus* (W. West) Teil.
=*Staurastrum cuspidatum* var. *maximum* W. West
29, 98, 124
Staurodesmus michiganensis (Johnson) Teil.
=*Arthrodesmus michiganensis* Johnson
94
Staurodesmus mucronatus (Ralfs ex Bréb.) Croasdale
=*Staurastrum mucronatum* Ralfs ex Bréb.
47, 60, 93, 100, 129
Staurodesmus mucronatus var. *subtriangularis* (W. & G.S. West) Croasdale

=*Staurastrum mucronatum* var. *subtriangulare* W. & G.S. West
43, 54, 58, 60, 98, 129
*Staurodesmus mucronulatus (*Nordst.) Compère
=*Arthrodesmus mucronulatus* var. *robustus* W. & G.S. West
47, 60
Staurodesmus o'mearii (Archer) Teil.
=*Staurastrum o'mearii* Archer
20, 21, 43, 47, 52, 60, 68, 74, 92, 99, 117, 124
=*Staurastrum o'mearii* var. *st.-johannense* Ir.-Mar.
60
Staurodesmus pachyrhynchus (Nordst.) Teil.
=*Staurastrum pachyrhynchum* Nordst.
1, 20, 21, 29, 40, 43, 47, 52, 54, 58, 60, 68, 88, 92, 98, 99, 100, 121, 124, 129
Staurodesmus pachyrhynchus var. *pseudopachyrhynchus* (Wolle) Teil.
=*Staurastrum pseudopachyrhynchum* Wolle
54
Staurodesmus patens (Nordst.) Croasdale
=*Staurastrum dejectum* var. *patens* Nordst.
20, 21, 124, 125
Staurodesmus phimus (Turn.) Thomasson
=*Arthrodesmus phimus* Turn.
20, 43, 53, 59, 60, 73
Staurodesmus phimus var. *occidentalis* (W. & G.S. West) Teil.
=*Arthrodesmus phimus* var. *occidentalis* W. & G.S. West
20
Staurodesmus quiriferus (W. & G.S. West) Teil.
77, 118
=*Arthrodesmus quiriferus* W. & G.S. West
76
Staurodesmus quiriferus f. *minus* (Hirano) Teil.
=*Arthrodesmus quiriferus* var. *minor* Ir.-Mar.
63
Staurodesmus sellulus (Ir.-Mar.) Teil.
=*Staurastrum sellulum* Ir.-Mar.
52, 68
Staurodesmus sibiricus (Borge) Teil.
=*Staurastrum clepsydra* var. *sibiricum* (Borge) W. & G.S. West
52, 60, 68
Staurodesmus subpygmaeus (W. West) Croasdale
=*Staurastrum subpygmaeum* W. West
129
Staurodesmus subpygmaeus var. *subangulatus* (W. & G.S. West) Teil.
=*Staurastrum subpygmaeum* var. *subangulatum* W. & G.S. West
129
Staurodesmus subtriangularis (Borge) Teil.
5
=*Arthrodesmus triangularis* var. *subtriangularis* (Borge) W. & G.S. West
20, 21, 27, 28, 29, 43, 47, 59, 63, 74, 99, 124
Staurodesmus subtriangularis var. *inflatus* (W. & G.S. West) Teil.
=*Arthrodesmus triangularis* var. *inflatus* W. & G.S. West
20, 21, 29, 59, 63, 99, 117, 124, 125
=*Arthrodesmus triangularis* var. *inflatus* f. *robusta* W. & G.S. West
29, 99, 124
=*Arthrodesmus triangularis* var. *subtriangularis* f. *mistassiniensis* Ir.-Mar.
53
Staurodesmus subulatus (Kütz.) Thomasson
=*Arthrodesmus subulatus* Kütz.
20, 21, 29, 31 (sous *Ankistrodesmus subulatus*), 43, 63, 74, 99, 117, 124
Staurodesmus subulatus f. *nordstedtii* (G.M. Sm.) Teil.
=*Arthrodesmus subulatus* var. *nordstedtii* G.M. Sm.
63
=?*Arthrodesmus convergens* var. *divergens* Ir.-Mar.
63
Staurodesmus subulatus var. *americanus* (Scott & Grönbl.) Teil.
=*Arthrodesmus subulatus* f. *americana* (Turn.) W. & G.S. West
21
Staurodesmus subulatus var. *subaequalis* (W. & G.S. West) Thomasson
=*Arthrodesmus subulatus* var. *subaequalis* W. & G.S. West
63
Staurodesmus triangularis (Lagerh.) Teil.
=*Arthrodesmus triangularis* Lagerh.
20, 22, 23, 27, 28, 29, 47, 63, 82, 87, 99, 109, 110, 112, 124, 126
Staurodesmus triangularis var. *latus* (Ir.-Mar.) Teil.
=*Arthrodesmus triangularis* var. *latum* Ir.-Mar.
60
Staurodesmus validus (W. & G.S. West) Thomasson
=*Arthrodesmus incus* var. *validus* W. & G.S. West
27, 28
Staurodesmus validus var. *subvalidus* (Grönbl.) Teil.
=*Arthrodesmus subvalidus* Grönbl.
53
Staurodesmus spp.
=*Arthrodesmus* spp.
1, 20, 22, 23, 29, 78, 82, 87, 99, 116, 124, 125, 126
Teilingia excavata (Ralfs) Bourrelly
20
=*Sphaerozosma excavatum* Ralfs
21, 27, 28, 43, 47, 60, 63, 73, 74, 82, 94, 98, 121, 124
Teilingia excavata var. *subquadrata* (W. & G.S. West) Stein
20

=*Sphaerozosma excavatum* var. *subquadratum* W. & G.S. West
43, 51, 63, 100, 124
Teilingia granulata (Roy & Biss.) Bourrelly
20
=*Sphaerozosma granulatum* Roy & Biss.
5, 21, 27, 28, 43, 47, 51, 60, 63, 92, 94 (*S. granulosum*), 99, 100, 117, 124, 125, 129
Teilingia wallichii var. *anglica* (W. & G.S. West) Förster
20
Tetmemorus brebissonii (Menegh.) Ralfs
5, 20, 43, 45, 51, 54, 59, 60, 70, 73, 74, 92, 100
Tetmemorus brebissonii var. *minus* De Bary
43, 45, 60, 100, 124
Tetmemorus granulatus (Bréb.) Ralfs
5, 43, 45, 51, 54, 59, 60, 73, 74, 99, 100, 117, 124
Tetmemorus granulatus var. *attenuatus* W. West
5, 21, 60
Tetmemorus laevis (Kütz.) Ralfs
5, 20, 21, 43, 60, 74, 97, 100
Tetmemorus laevis var. *minutus* (De Bary) Krieger
5
=*T. minutus* De Bary
45, 59, 60, 100
Tetmemorus spp.
20, 124
Triploceras gracile Bail.
5, 20, 21, 29, 43, 49, 54, 59, 60, 70, 73, 74, 98, 99, 100, 117, 124, 125, 126
Triploceras gracile var. *bispinatum* Taylor
43, 60, 100, 124
Triploceras verticillatum Bail.
5, 20, 21, 43, 49, 59, 60, 70, 73, 74, 100
Triploceras verticillatum var. *taylorii* Scott & Grönbl.
=?*T. verticillatum* f. *triradiatum* Taylor
43, 60, 100
Triploceras sp.
20
Xanthidium aculeatum Ehrenb. ex Ralfs
39
Xanthidium antilopaeum (Bréb.) Kütz.
6, 20, 21, 29, 39, 47, 51, 54, 60, 74, 82, 87, 92, 94, 96, 97, 99, 109, 110, 112, 124
=*X. antilopaeum* forma Ir.-Mar.
74
Xanthidium antilopaeum f. *callosum* Cushman
=*X. antilopaeum* var. *callosum* (Cushman) Ir.-Mar.
47, 54, 56, 60, 74
=*X. antilopaeum* var. *callosum* f. *majus* Ir.-Mar.
74
Xanthidium antilopaeum var. *canadense* Joshua
5, 20, 43, 47, 56, 60, 74
Xanthidium antilopaeum var. *hebridarum* W. & G.S. West
20, 43, 47, 51, 54, 56, 60, 73, 74, 92, 97, 124
Xanthidium antilopaeum var. *incrassatum* (Grönbl.) Förster
20
=*X. antilopaeum* var. *laeve* f. *incrassatum* Grönbl.
5, 21
Xanthidium antilopaeum var. *laeve* Schmidle
20, 21
Xanthidium antilopaeum var. *limneticum* G.M. Sm.
20, 47
Xanthidium antilopaeum var. *minneapoliense* Wolle
20, 21, 43, 47, 56, 60, 73, 74, 100
Xanthidium antilopaeum var. *planum* Roll
=*X. antilopaeum* var. *quebecense* Ir.-Mar.
43, 47, 51, 56, 60, 73, 74
=*X. antilopaeum* var. *quebecense* f. *angulatum* Ir.-Mar.
51
Xanthidium antilopaeum var. *planum* f. *angustatum* (Ir.-Mar.) Prescott, Vinyard & Bicudo
=*X. antilopaeum* var. *quebecense* f. *angustatum* Ir.-Mar.
74
Xanthidium antilopaeum var. *polymazum* Nordst.
4, 5, 20, 21, 27, 28, 29, 43, 47, 51, 54, 56, 60, 73, 74, 92, 97, 98, 99, 100, 124, 125
Xanthidium antilopaeum var. *pseudoalpinum* (Ir.-Mar.) Prescott, Vinyard & Bicudo
=*X. antilopaeum* var. *subalpinum* (Wolle) Ir.-Mar.
51, 74
Xanthidium armatum (Bréb.) Ralfs
5, 20, 21, 43, 47, 51, 60, 73, 74, 87, 99, 100, 117, 124
Xanthidium armatum f. *inerme* Ir.-Mar.
60
Xanthidium armatum var. *cervicorne* W. & G.S. West
60, 98
Xanthidium armatum var. *fissum* Nordst.
20, 21, 43, 47, 51, 54, 60, 73, 74, 99, 100, 117, 124
Xanthidium armatum var. *irregulare* W. West
60
Xanthidium armatum var. *mediolaeve* G.M. Sm.
5, 20, 21, 43, 47, 51, 60, 99, 100, 117, 124
Xanthidium bengalicum Turn.
20
Xanthidium bifidum (Bréb.) Defl.
=*Arthrodesmus bifidus* Bréb.
94, 124, 126
***Xanthidium bucerium* (Ir.-Mar.) Poulin, comb. nov.**
Basionyme: *Arthrodesmus bucerius* Irénée-Marie 1952a, p. 15, pl. 1, figs. 5-7.
59
Xanthidium controversum W. & G.S. West
20, 21, 29, 60, 99, 124
Xanthidium controversum var. *angulosum* Ir.-Mar.
60, 74
Xanthidium cristatum Bréb. ex Ralfs
20, 21, 43, 47, 51, 56, 60, 73, 74, 92, 93, 124, 125

Xanthidium cristatum var. *hipparquii* Ir.-Mar.
5, 20, 21, 43, 47, 56, 60, 74, 100
=*X. cristatum* var. *hipparquii* forma Ir.-Mar.
74
=*X. cristatum* var. *hipparquii* f. *depauperatum* Ir.-Mar.
60
Xanthidium cristatum var. *papilliferum* Ir.-Mar.
43, 51
Xanthidium cristatum var. *scrobiculatum* Scott & Grönbl.
5
Xanthidium cristatum var. *uncinatum* Bréb.
5, 6, 20, 21, 29, 43, 47, 51, 56, 60, 74, 92, 98, 99, 100, 124
Xanthidium cristatum var. *uncinatum* f. *mucronatum* W. West
43, 51, 56, 60
Xanthidium cristatum var. *uncinatum* f. *polonicum* Gutw.
43
Xanthidium cristatum var. *uncinatum* f. *simplex* Ir.-Mar.
43, 47
Xanthidium cristatum var. *uncinatum* f. *triquetrum* Ir.-Mar.
43, 44
Xanthidium impar (Jacobsen) Defl.
=*Arthrodesmus impar* (Jacobsen) Grönbl.
47, 60
Xanthidium mauricianum Ir.-Mar.
51, 60
Xanthidium obsoletum Taylor
43, 60
Xanthidium octocorne Ralfs
=*Arthrodesmus octocornis* Ehrenb. ex Archer
5, 20, 21, 22, 23, 43, 47, 51, 53, 59, 60, 63, 73, 74, 76, 82, 99, 100, 117, 124, 125, 126
***Xanthidium octocorne* var. *mamillatum* (Scott & Grönbl.) Poulin, comb. nov.**
Basionyme: *Arthrodesmus octocornis* var. *mamillatus* Scott & Grönblad 1957, p. 27, pl. 18, figs. 18, 19.
124
***Xanthidium octocorne* var. *tenue* (Ir.-Mar.) Poulin, comb. nov.**
Basionyme: *Arthrodesmus octocornis* var. *tenuis* Irénée-Marie 1954c, p. 93, fig. 3.
63 (var. *tenue*)
Xanthidium pseudobengalicum Grönbl.
5, 20, 29, 43, 47, 54, 56, 74, 98, 99, 100, 124
Xanthidium subhastiferum W. West
20, 29, 39, 43, 47, 73, 97, 98, 99, 124
Xanthidium subhastiferum var. *johnsonii* (W. & G.S. West) G.M. Sm.
94
Xanthidium subhastiferum var. *murrayi* f. *triquetrum* W. & G.S. West
98
Xanthidium torreyi Wolle
124
Xanthidium wewahitchkense Scott & Grönbl.
20
Xanthidium spp.
20, 87, 124, 125, 126

Zygnematales

Mesotaeniaceae

Cylindrocystis brebissonii (Menegh. ex Ralfs) De Bary
5, 20, 21, 43, 47, 59, 60, 63, 73, 74, 92, 93, 97
Cylindrocystis brebissonii var. *minor* W. & G.S. West
20, 21, 43, 47, 54, 59, 60, 63, 92, 100
Cylindrocystis crassa De Bary
63
Genicularia spirotaenia De Bary
20
Genicularia sp.
18
Gonatozygon aculeatum Hastings
5, 20, 21, 43, 47, 60, 63, 100, 124, 125
Gonatozygon aculeatum var. *gracile* Grönbl.
20, 21
Gonatozygon brebissonii De Bary
20, 43, 47, 59, 60, 63, 73, 74, 92, 94, 97, 100, 124, 126
Gonatozygon brebissonii var. *laeve* (Hilse) W. & G.S. West
52, 63
Gonatozygon kinahani (Archer) Rabenh.
20, 21, 43, 47, 52, 54, 59, 60, 63, 73, 74, 90, 92
Gonatozygon kinahani var. *majus* Taylor
52, 63, 74
Gonatozygon monotaenium De Bary
20, 21, 29, 47, 90, 92, 94, 99, 124
Gonatozygon pilosum Wolle
20, 21, 29, 43, 47, 60, 63, 74, 99, 100, 124, 125, 126
Gonatozygon spp.
20, 22, 29, 39, 99, 124, 125, 126
Mesotaenium aplanosporum Taft
47, 60, 73
Mesotaenium chlamydosporum De Bary
60
Mesotaenium degreyi Turn.
54, 63, 73, 74
Mesotaenium degreyi f. *majus* W. & G.S. West
63
Mesotaenium degreyi var. *breve* W. West
54, 63
Mesotaenium endlicherianum Näg.
47, 60, 73, 74
=*M. purpureum* W. & G.S. West
47, 54, 60
Mesotaenium endlicherianum var. *grande* Nordst.
47, 60

Mesotaenium macrococcum (Kütz.) Roy & Biss.
20, 47, 54, 60, 92
Mesotaenium macrococcum var. *minus* (De Bary) Compère
=*M. macrococcum* var. *micrococcum* (Kütz.) W. & G.S. West
5
Mesotaenium mirificum Archer
20
Mesotaenium spp.
124, 125, 126
Netrium digitus (Bréb. ex Ralfs) Itz. & Rothe
5, 6, 20, 21, 29, 40, 43, 47, 52, 54, 59, 60, 63, 73, 74, 87, 92, 93, 94, 96, 97, 98, 99, 100, 117, 124, 125
Netrium digitus f. *ellipticum* Ir.-Mar.
43, 47, 59, 60, 74
Netrium digitus var. *lamellosum* (Bréb.) Grönbl.
=*N. digitus* var. *constrictum* (W. West) W. & G.S. West
43, 47, 59, 60, 73, 74
Netrium digitus var. *naegelii* (Bréb.) Krieger
5, 63
=*N. naegelii* (Bréb.) W. & G.S. West
20, 21, 43, 74, 124
Netrium interruptum (Bréb. ex Ralfs) Lütk.
20, 21, 43, 47, 52, 59, 60, 63, 74, 97
Netrium oblongum (De Bary) Lütk.
20, 21, 43, 47, 52, 54, 59, 60, 63, 74, 99, 117, 124
=*N. oblongum* forma Ir.-Mar.
43
Netrium oblongum var. *acuminatum* Ir.-Mar.
63
Netrium oblongum var. *cylindricum* W. & G.S. West
20, 43, 47, 60, 63
Netrium spp.
20, 124, 125, 126
Roya anglica G.S. West
59, 60, 63, 73
Roya cambrica W. & G.S. West
52, 59, 63, 74
Roya cambrica var. *limnetica* W. & G.S. West
52, 59, 63
Roya obtusa (Bréb.) W. & G.S. West
47, 60, 73
Roya obtusa var. *montana* W. & G.S. West
47, 60
Roya sp.
20
Spirotaenia condensata Bréb. ex Ralfs
5, 20, 21, 43, 47, 54, 59, 60, 63, 73, 96, 97, 100
Spirotaenia obscura Ralfs
43, 47, 60, 97, 100
Spirotaenia trabeculata A. Br.
43, 63
Spirotaenia truncata Archer
59
Spirotaenia sp.
20

Zygnematales

Zygnemataceae

Mougeotia laetevirens (A. Br.) Wittr.
20, 21
Mougeotia macrospora (Wolle) De Toni
97
Mougeotia nummuloides (Hass.) De Toni
101
Mougeotia punctata Wittr.
124
Mougeotia quadrangulata Hass.
89, 93
Mougeotia spp.
1, 6, 20, 22, 23, 27, 28, 29, 37, 39, 40, 42, 76, 78, 87, 88, 90, 92, 93, 94, 96, 97, 98, 99, 100, 101, 106, 109, 110, 111, 112, 117, 121, 124, 125, 126, 129
Sirogonium sp.
20
Spirogyra colligata Hodgetts
20
Spirogyra crassa (Kütz.) Czurda
121
Spirogyra fluviatilis Hilse
101
Spirogyra gratiana Trans.
20
Spirogyra grevilleana (Hass.) Kütz.
97, 121
Spirogyra inflata var. *foveolata* Trans.
129
Spirogyra longata (Vauch.) Kütz.
6, 97
Spirogyra maxima (Hass.) Wittr.
97
Spirogyra nitida (Dillw.) Link
97
Spirogyra pseudocylindrica Prescott
113
Spirogyra rivularis (Hass.) Rabenh.
121
Spirogyra setiformis (Roth) Kütz.
6, 101
Spirogyra spreeiana Rabenh.
97
Spirogyra stictica (Engl. Bot.) Wille
121
Spirogyra subsalsa Kütz.
32
Spirogyra sulcata Blum
121
Spirogyra tenuissima (Hass.) Kütz.
97
Spirogyra weberi Kütz.
20, 97
Spirogyra spp.
1, 20, 21, 22, 29, 36, 37, 39, 40, 76, 87, 88, 90, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101 (?*S. orbicu-*

laris (Hass.)Kütz./?*S. setiformis* (Roth) Kütz.).
111, 117, 121, 124, 125, 126, 129
Zygnema curvatum C. Ag.
80
Zygnema cyanosporum Cleve
129 (*Z. cyanospermum*)
Zygnema insigne (Hass.) Kütz.
101
Zygnema pellucidum Hass.
80
Zygnema stellinum (Vauch.) C. Ag.
20, 97
Zygnema vaucherii C. Ag.
101
Zygnema spp.
1, 6, 20, 21, 29, 36, 37, 40, 88, 90, 92, 93, 94, 95, 96, 97, 99, 100, 101, 109, 117, 121, 124, 125
Zygogonium ericetorum Kütz.
37

Bacillariophyta [13]
Coscinodiscophyceae
Aulacoseirales

Aulacoseira ambigua (Grun.) Simonsen
20
=*Melosira ambigua* (Grun.) O. Müll.
5, 21, 27, 28, 29, 87, 99, 103, 124, 126
Aulacoseira canadensis (Hust.) Simonsen
=*Melosira canadensis* Hust.
5
Aulacoseira distans (Ehrenb.) Simonsen
=*Melosira distans* (Ehrenb.) Kütz.
26, 27, 28, 29, 30, 87, 88, 98, 99, 110, 112, 121, 124
=*A. distans* var. *nivalis* (W. Sm.) Haworth
41
Aulacoseira distans var. *africana* (O. Müll.) Simonsen
=*Melosira distans* var. *africana* O. Müll.
5
Aulacoseira distans var. *alpigena* (Grun.) Simonsen
41
=*Melosira distans* var. *alpigena* Grun.
27, 28
Aulacoseira granulata (Ehrenb.) Simonsen
20
=*Melosira granulata* (Ehrenb.) Ralfs
1, 2, 24, 25, 29, 78, 88, 97, 98, 99, 100, 105, 111, 124
Aulacoseira granulata var. *angustissima* (O. Müll.) Simonsen
=*Melosira granulata* var. *angustissima* O. Müll.
27, 28, 29, 88, 98, 99, 110, 111, 112, 121, 124
Aulacoseira granulata var. *valida* (Hust.) Simonsen
=*Melosira granulata* var. *valida* Hust.
29, 99 (f. *valida*), 124 (f. *valida*)
Aulacoseira herzogii (Lemm.) Simonsen
=*Melosira herzogii* Lemm.
1, 88
Aulacoseira islandica (O. Müll.) Simonsen
=*Melosira islandica* O. Müll.
27, 28, 29, 30, 32, 77, 99, 103, 105, 110, 111, 112, 117, 118, 121, 124, 126
Aulacoseira islandica ssp. *helvetica* (O. Müll.) Simonsen
=*Melosira islandica* ssp. *helvetica* O. Müll.
1, 24, 25, 27, 28, 88, 103, 121
Aulacoseira italica (Ehrenb.) Simonsen
=*Melosira italica* (Ehrenb.) Kütz.
5, 24, 25, 29, 30, 88, 98, 99, 106, 109, 110, 111, 112, 116, 117, 121, 124
Aulacoseira italica f. *crenulata* (Ehrenb.) Ross
20
=*Melosira crenulata* (Ehrenb.) Kütz.
2, 3
Aulacoseira italica var. *tenuissima* (Grun.) Simonsen
=*Melosira italica* var. *tenuissima* (Grun.) O. Müll.
5
Aulacoseira italica ssp. *subarctica* (O. Müll.) Simonsen
=*Melosira italica* ssp. *subarctica* O. Müll.
5, 27, 28, 29, 30, 98, 99, 103, 116, 117, 121, 124
Aulacoseira lirata (Ehrenb.) Ross
41
=*Melosira lirata* (Ehrenb.) Kütz.
41
Aulacoseira perglabra (Østr.) Haworth
=*A. lirata* var. *perglabra* (Østr.) Ross
41
Aulacoseira perglabra var. *florinae* (Camburn) Haworth
=*Melosira perglabra* var. *florinae* Camburn
41

Chaetocerotales

Chaetoceros spp.
29, 88, 92, 95, 124

Coscinodiscales

Coscinodiscus spp.
20, 29, 95, 97, 99, 116, 117, 124

Melosirales

Melosira moniliformis (O.F. Müll.) C. Ag.
26
Melosira undulata (Ehrenb.) Kütz.
1, 24, 25, 29, 88, 97, 98, 99, 121, 124
Melosira varians C. Ag.
1, 2, 3, 20, 21, 24, 25, 29, 30, 88, 92, 97, 98, 99, 105, 110, 111, 112, 121, 124
Melosira spp.
3, 22, 23, 27, 28, 29, 39, 76, 82, 87, 95, 99, 103, 109, 110, 112, 116, 124, 125, 126

Orthoseirales

Orthoseira epidendron (Ehrenb.) Crawford
=*Melosira roeseana* Rabenh.
124

Paraliales
Ellerbeckia arenaria (Moore ex Ralfs) Crawford
=*Melosira arenaria* Moore ex Ralfs
2, 3

Rhizosoleniales
Rhizosolenia longiseta Zach.
88, 121, 124
Rhizosolenia spp.
22, 39, 95, 124
Urosolenia eriensis (H.L. Sm.) Round & Crawford
=*Rhizosolenia eriensis* H.L. Sm.
1, 5, 20, 21, 27, 28, 29, 76, 77, 78, 88, 98, 99, 103, 106, 110, 111, 112, 116, 118, 124, 125, 126
***Urosolenia eriensis* var. *morsa* (W. & G.S. West) Poulin, comb. nov.**
Basionyme: *Rhizosolenia eriensis* var. *morsa* W. & G.S. West 1905, p. 509, pl. 6, fig. 23.
27, 28, 29, 99, 124

Thalassiosirales
Cyclotella antiqua W. Sm.
97, 119
Cyclotella atomus Hust.
76, 103
Cyclotella bodanica Grun.
1, 5, 27, 28, 29, 31, 88, 98, 99, 103, 105, 116, 117, 121, 124, 125, 126
Cyclotella glomerata Bachmann
76, 103, 121
Cyclotella krammeri Håkansson
=*C. kuetzingiana* Thwaites
32, 33, 111
Cyclotella meneghiniana Kütz.
1, 2, 30, 98, 105, 111, 118, 121, 124
Cyclotella ocellata Pant.
27, 28, 29, 76, 99, 103, 118, 124
Cyclotella radiosa (Grun.) Lemm.
=*C. comta* (Ehrenb.) Kütz.
2 (*C. compta*), 5, 20, 21, 24, 25, 27, 28, 88, 100, 103, 105, 109, 111
Cyclotella rossii Håkansson
=*C. comta* var. *oligactis* (Ehrenb.) Grun.
20, 21, 41
Cyclotella stelligera (Cleve & Grun.) V.H.
5, 20, 21, 30, 41, 78, 99, 103, 105, 121, 124, 125, 126
Cyclotella spp.
20, 22, 23, 27, 28, 29, 39, 76, 95, 99, 106, 110, 112, 116, 118, 121, 124, 125, 126
Cyclostephanos dubius (Fricke) Round
=*Stephanodiscus dubius* (Fricke) Hust.
29, 98, 99, 124
Cyclostephanos invisitatus (Hohn & Hellerman) Theriot, Stoermer & Håkansson
=*Stephanodiscus invisitatus* Hohn & Hellerman
76
Skeletonema subsalsum (Cleve-Euler) Bethge
88
Stephanodiscus binderanus (Kütz.) Krieger
1, 24, 25, 78, 88, 98, 105, 111, 121
=*Melosira binderana* Kütz.
30
Stephanodiscus hantzschii Grun.
29, 76, 99, 111, 124
Stephanodiscus minutulus (Kütz.) Round
=*S. astraea* var. *minutula* (Kütz.) Grun.
30, 76, 104, 121
Stephanodiscus niagarae Ehrenb.
2, 3, 24, 25, 88, 97, 124
=?*Stephanodiscus astraea*[19](Ehrenb.) Grun.
1, 29, 30, 76, 88, 98, 99, 103, 117, 119, 121, 124 (aussi sous *Coscinodiscus astraea*)
Stephanodiscus spp.
1, 22, 23, 29, 39, 76, 99, 106, 117, 124, 125, 126

Fragilariophyceae
Fragilariales
Amphicampa sp.
20
Asterionella bleakeleyi W. Sm.
29, 99, 124
Asterionella formosa Hass.
1, 3, 5, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 39, 41, 76, 78, 82, 87, 88, 95, 97, 98, 99, 100, 103, 104, 106, 109, 110, 111, 112, 116, 117, 118, 121, 124, 125, 126
=*A. formosa* var. *subtilis* Grun.
3
=*A. formosa* var. *subtilissima* Grun.
3
Asterionella gracillima (Hantzsch) Heib.
76 (*A. gracile*), 110, 112
=*A. formosa* var. *gracillima* (Hantzsch) Grun.
3
Asterionella ralfsii var. *americana* Körner
41
Asterionella spp.
20, 95, 124
Ctenophora pulchella (Ralfs ex Kütz.) Williams & Round
=*Synedra pulchella* Ralfs ex Kütz.
1, 29, 30, 88, 98, 99, 105, 111, 119, 121, 124
Diatoma anceps (Ehrenb.) Kirchn.
21, 92, 121, 124
=*Meridion anceps* (Ehrenb.) Williams
20
Diatoma hyemalis (Roth) Heib.
32
Diatoma mesodon (Ehrenb.) Kütz.
=*D. hiemalis* var. *mesodon* (Ehrenb.) Grun.
27, 28, 124, 125, 126
Diatoma tenuis C. Ag.
1, 30, 88, 105, 121, 124
Diatoma tenuis var. *elongata* Lyngb.
1, 30, 88, 98, 121, 124, 125, 126
=*D. elongata* (Lyngb.) C. Ag.
24, 25, 26, 27, 28, 39, 99, 110, 111, 112, 117

Diatoma vulgaris Bory
1, 3, 24, 25, 30, 88, 90, 92, 98, 105, 111, 116, 121, 124, 125, 126
Diatoma vulgaris var. *brevis* Grun.
30, 121
Diatoma vulgaris var. *ovalis* (Fricke) Hust.
121
Diatoma spp.
20, 22, 39, 82, 92, 95, 99, 117, 118, 124, 125, 126
Fragilaria capucina Desm.
1, 20, 21, 24, 25, 26, 29, 30, 31, 32, 88, 97, 98, 99, 101, 103, 105, 111, 117, 124
Fragilaria capucina var. *lanceolata* Grun.
27, 28, 29, 121, 124
Fragilaria capucina var. *mesolepta* (Rabenh.) Rabenh.
121
Fragilaria capucina var. *rumpens* (Kütz.) Lange-Bertalot
=*Synedra rumpens* Kütz.
29, 78, 99, 121, 124
Fragilaria crotonensis Kitton
1, 5, 20, 21, 23, 24, 25, 26, 28, 29, 30, 31, 32, 33, 39, 76, 78, 82, 87, 88, 97, 98, 99, 105, 111, 116, 121, 124, 125, 126
=?*Synedra crotonensis* Edwards ex Cleve & Möll.
2
Fragilaria incisa (Boyer) Lange-Bertalot
=*Synedra incisa* Boyer
121
Fragilaria intermedia (Grun.) Grun.
111
Fragilaria minuscula (Grun.) Williams & Round
=*Synedra minuscula* Grun.
29, 99, 111, 124
Fragilaria radians (Kütz.) Williams & Round
20
=*Synedra radians* Kütz.
21, 27, 28, 29, 99, 121, 124
=*S. acus* var. *radians* (Kütz.) Hust.
42, 77, 118
Fragilaria reicheltii (Voigt) Lange-Bertalot
=*Centronella reicheltii* Voigt
116, 124, 125, 126
Fragilaria socia (Wallace) Lange-Bertalot
=*Synedra socia* Wallace
1, 88
Fragilaria subsalina (Grun.) Lange-Bertalot
=*F. virescens* var. *subsalina* Grun.
41
Fragilaria tenera (W. Sm.) Lange-Bertalot
=*Synedra tenera* W. Sm.
33, 78, 103, 121
Fragilaria vaucheriae (Kütz.) Petersen
30, 98, 105, 121
=*Synedra vaucheriae* (Kütz.) Kütz.
32
Fragilaria vaucheriae var. *capitellata* (Grun.) Ross
30, 121
Fragilaria spp.
20, 22, 23, 29, 39, 87, 92, 95, 99, 124, 125, 126
Fragilariforma constricta (Ehrenb.) Williams & Round
=*Fragilaria constricta* Ehrenb.
29, 76, 98, 99, 103, 124
Fragilariforma constricta f. *stricta* (A. Cleve) Poulin
20
=*Fragilaria constricta* f. *stricta* (A. Cleve) Hust.
21
Fragilariforma virescens (Ralfs) Williams & Round
=*Fragilaria virescens* Ralfs
2 (aussi sous *Staurosira virescens*), 3, 29, 41, 87, 98, 99, 116, 121, 124, 125
***Fragilariforma virescens* var. *capitata* (Østr.) Poulin, comb. nov.**
Basionyme: *Fragilaria virescens* var. *capitata* Østrup 1910, p. 193, pl. 5, fig. 125
98
Hannaea arcus (Ehrenb.) Patr.
29, 30, 98, 99, 121, 124
=*Ceratoneis arcus* (Ehrenb.) Kütz.
1, 3, 27, 28, 29, 78, 88, 97, 98, 99, 111, 121, 124, 126
Hannaea spp.
=*Ceratoneis* spp.
124, 126
Martyana martyi (Hérib.) Round
=*Opephora martyi* Hérib.
24, 25, 88, 111
Meridion circulare (Grev.) C. Ag.
2, 3, 20, 21, 27, 28, 30, 97, 98, 111, 121, 124, 125, 126
Meridion circulare var. *constrictum* (Ralfs) V.H.
97, 124, 126
=*M. constrictum* Ralfs
2
Meridion sp.
92
Pseudostaurosira brevistriata (Grun.) Williams & Round
=*Fragilaria brevistriata* Grun.
2, 31, 32, 103, 105
=*Staurosira brevistriata* Grun.
2
***Pseudostaurosira brevistriata* var. *inflata* (Pant.) Poulin, comb. nov.**
Basionyme: *Fragilaria inflata* Pantocsek 1902, p. 79, pl. 9, figs. 219-221
=*Fragilaria brevistriata* var. *inflata* (Pant.) Hust.
30, 121
Staurosira construens Ehrenb.
=*Fragilaria construens* (Ehrenb.) Grun.
29, 30, 33, 99, 103, 105, 121, 124
Staurosira construens var. *binodis* (Ehrenb.) Hamilton
=*Fragilaria construens* var. *binodis* (Ehrenb.) Grun.
1, 88, 124

=*Fragilaria construens* var. *bigibba* A. Cleve
103
***Staurosira construens* var. *triundulata* (Reichelt ex Hartz & Østr.) Hamilton, comb. nov.**
Basionyme: *Fragilaria construens* var. *triundulata* Reichelt ex Hartz & Østrup 1899, p. 57, pl. 2, fig. 15
=*Fragilaria sinuata* M. Perag.
121
Staurosira construens var. *venter* (Ehrenb.) Hamilton
=*Fragilaria construens* var. *venter* (Ehrenb.) Grun.
121, 124
=*Fragilaria construens* var. *pumila* Grun.
121
Staurosirella leptostauron (Ehrenb.) Williams & Round
=*Fragilaria leptostauron* (Ehrenb.) Hust.
33, 100, 105, 124, 125, 126
=*Fragilaria harrisonii* (W. Sm.) Grun.
24, 25, 88
***Staurosirella leptostauron* var. *dubia* (Grun.) Poulin, comb. nov.**
Basionyme: *Fragilaria harrisonii* var. *dubia* Grunow 1862, p. 368, pl. 7, figs. 8a-d
=*Fragilaria leptostauron* var. *dubia* (Grun.) Hust.
124
Staurosirella pinnata (Ehrenb.) Williams & Round
=*Fragilaria pinnata* Ehrenb.
1, 29, 30, 32, 33, 88, 98, 99, 103, 105, 111, 121, 124, 125
***Staurosirella pinnata* var. *lancettula* (Schumann) Poulin, comb. nov.**
Basionyme: *Fragilaria lancettula* Schumann 1867, p. 52, pl. 1, fig. 4
=*Fragilaria pinnata* var. *lancettula* (Schumann) Hust.
30, 121
Synedra acus Kütz.
2, 3, 20, 21, 29, 30, 31, 33, 41, 76, 98, 99, 106, 109, 110, 111, 112, 121, 124, 125, 126
Synedra amphicephala Kütz.
1, 29, 88, 99, 124, 126
Synedra amphicephala var. *austriaca* (Grun.) Hust.
29, 121, 124
Synedra berolinensis Lemm.
121, 124, 126
Synedra capitata Ehrenb.
3
Synedra cyclopum Brutschy
30, 121
Synedra delicatissima W. Sm.
29, 30, 99, 121, 124
Synedra delicatissima var. *angustissima* Grun.
1, 2, 3, 29, 88, 99, 121, 124
=*S. acus* var. *angustissima* (Grun.) V.H.
76
Synedra famelica Kütz.
121
Synedra filiformis var. *exilis* Cleve-Euler
121
Synedra nana Meister
33, 106, 124, 126
?*Synedra rumpens* var. *familiaris*[20](Kütz.) Hust.
29, 30, 98, 99, 121, 124
Synedra ulna (Nitzsch) Ehrenb.
1, 2, 20, 21, 22, 28, 29, 30, 33, 39, 76, 78, 88, 90, 92, 98, 99, 101, 103, 105, 106, 110, 111, 112, 117, 121, 124, 125, 126
=*S. ulna* var. *splendens* (Kütz.) V.H.
97
=*S. subaequalis* Grun.
2
Synedra ulna var. *contracta* Østr.
=*S. ulna* var. *genuina* f. *constricta* Mayer
98
=*S. ulna* var. *ramesii* (Hérib.) Hust.
30, 121
Synedra ulna var. *danica* (Kütz.) V.H.
20, 21, 24, 25, 27, 28, 88, 111
=*S. danica* Kütz.
2
=*S. ulna* var. *chaseana* Thomas
29, 99, 124
Synedra ulna var. *longissima* (W. Sm.) Brun
20, 21, 97
=*S. ulna* var. *biceps* (Kütz.) Schönf.
2
Synedra utermoehlii Hust.
124
Synedra spp.
3, 20, 22, 23, 29, 39, 76, 82, 95, 99, 106, 116, 121, 124, 125, 126
Tabularia fasciculata (C. Ag.) Williams & Round
20
=*Synedra fasciculata* (C. Ag.) Kütz.
21, 29, 98, 99, 124
=*Synedra fasciculata* var. *truncata* (Grev.) Patr.
29, 99, 124
=*Synedra capitulata* Castracane
2 (*S. capitula*)
=*Synedra tabulata* var. *delicatula* (Grun.) Ross
119
Tabularia tabulata (C. Ag.) Snoeijs
=*Synedra tabulata* (C. Ag.) Kütz.
29, 32, 111, 124
=*Synedra tabulata* var. *obtusa* (Arnott ex V.H.) Hust.
119

Tabellariales

Tabellaria binalis (Ehrenb.) Grun.
39
Tabellaria fenestrata (Lyngb.) Kütz.
2, 3, 5, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 39, 77, 78, 82, 87, 88, 90, 92, 95, 97, 98, 99, 100, 104, 105, 106, 109, 111, 116, 117, 118, 119, 121, 124, 125, 126

Tabellaria flocculosa (Roth) Kütz.
1, 2, 3, 5, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 33, 39, 41, 42, 76, 78, 82, 87, 88, 90, 92, 93, 94, 97, 98, 99, 100, 101, 105, 106, 107, 109, 111, 116, 117, 118, 119, 121, 124, 125, 126
Tabellaria flocculosa var. *asterionelloides* (Grun.) Knudson
20, 29, 97, 98, 99, 110, 111, 112, 124
=*T. fenestrata* var. *asterionelloides* Grun.
5, 27, 28
Tabellaria flocculosa var. *geniculata* (A. Cleve) Knudson
41
Tabellaria quadriseptata Knudson
20, 41, 42 (sous *T. fenestrata*)
Tabellaria spp.
20, 23, 87, 92, 110, 112, 124
Tetracyclus lacustris Ralfs
2, 87, 124
=*T. pagesii* Hérib.
2
Tetracyclus rupestris (A. Br.) Grun.
124
Tetracyclus sp.
39

Bacillariophyceae
Eunotiales

Actinella punctata Lewis
20, 21, 29, 41, 42, 76, 77, 99, 100, 117, 124
Actinella spp.
124, 126
Eunotia arctica Hust.
41
Eunotia arcus Ehrenb.
29, 32, 99, 111, 116, 117, 124, 126
=*Himantidium arcus* (Ehrenb.) Ehrenb.
2
Eunotia arcus var. *fallax* Hust.
27, 28
Eunotia bidentula W. Sm.
20, 21, 29, 41, 99, 124
Eunotia bigibba Kütz.
41
Eunotia bigibba var. *pumila* Grun.
41, 103
Eunotia bilunaris (Ehrenb.) Mills
=*E. curvata* (Kütz.) Lagerst.
20, 21, 27, 28, 29, 41, 42, 98, 99, 107, 117, 119, 121, 124, 125, 126
=*E. lunaris* (Ehrenb.) Grun.
2, 24, 25, 41, 88, 97, 103, 111, 124
Eunotia bilunaris var. *mucophila* Lange-Bertalot & Nörpel
=*E. lunaris* var. *subarcuata* (Näg. ex Kütz.) Grun.
41
Eunotia clevei[21] Cleve
99, 117, 124
?*Eunotia curvata* var. *capitata* (Grun.) Woodh. & Tweed
20, 21, 29, 31, 124
Eunotia denticulata (Bréb. ex Kütz.) Rabenh.
99, 117 (*E. denticula*), 124
Eunotia diodon Ehrenb.
20, 21, 29, 31, 32, 41, 99, 124, 125, 126
Eunotia elegans Østr.
27, 28, 29, 41, 99, 116, 124, 125, 126
Eunotia exigua (Bréb. ex Kütz.) Rabenh.
20, 21, 32, 33, 41, 99, 107, 111, 117, 119, 124, 125, 126
Eunotia exigua var. *undulata* Magdeberg
=*E. exigua* var. *bidens* Hust.
111
Eunotia fallax A. Cleve
27, 28, 29, 41, 98, 99, 124
Eunotia fallax var. *groenlandica* (Grun.) Lange-Bertalot & Nörpel
=*E. fallax* var. *gracillima* Krasske
29, 99, 119, 124
Eunotia flexuosa Kütz.
20, 21, 29, 41, 99, 103, 110, 111, 112, 124, 126
Eunotia flexuosa var. *eurycephala* Grun.
20, 21
Eunotia gibbosa Grun.
27, 28
Eunotia glacialis Meister
1, 20, 21, 29, 88, 99, 124, 125, 126
=*E. gracilis* (Ehrenb.) Rabenh.
29, 97, 99
Eunotia hemicyclus (Ehrenb.) Ralfs
100
Eunotia hexaglyphis Ehrenb.
20, 21
=*E. senaria* Ehrenb.
21
Eunotia incisa W. Sm. ex Greg.
1, 20, 21, 29, 30, 88, 98, 99, 121, 124, 125
Eunotia indica Grun.
121
Eunotia kocheliensis O. Müll.
124
Eunotia lapponica Grun. ex A. Cleve
41, 99, 117, 124, 126
Eunotia major (W. Sm.) Rabenh.
1, 2, 20, 21 (*E. maior*), 29 (*E. maior*), 88 (*E. maior*), 98 (*E. maior*), 99, 100, 105, 121 (*E. maior*), 124 (*E. maior*), 126 (*E. maior*)
Eunotia meisteri var. *bidens* Hust.
41
Eunotia monodon Ehrenb.
2, 3, 27, 28, 41, 99, 117, 119, 124, 125
Eunotia naegelii Migula
20, 21, 27, 28, 29, 99, 117, 124, 125, 126
=*E. alpina* (Näg. ex Kütz.) Hust.
41
Eunotia nodosa Ehrenb.
=*E. formica* Ehrenb.
3, 29, 99, 124

Eunotia nymanniana Grun.
117, 124
Eunotia papilio (Ehrenb.) Hust.
20
Eunotia parallela Ehrenb.
20, 21, 29, 32, 41, 99, 110, 112, 117, 121, 124, 125, 126
=*E. pseudoparallela* Cleve-Euler
119
Eunotia pectinalis (O. Müll.) Rabenh.
2, 3, 20, 21, 27, 28, 29, 30, 41, 42, 97, 98, 99, 100, 103, 105, 107, 121, 124, 125
Eunotia pectinalis var. *minor* (Kütz.) Rabenh.
20, 21, 24, 25, 27, 28, 29, 30, 42, 88, 99, 103, 119, 121, 124, 125, 126 (f. *minor*)
Eunotia pectinalis var. *recta* A. Mayer ex Patr.
42
Eunotia pectinalis var. *ventricosa* Grun.
20, 21, 27, 28, 29, 99, 103, 124
=*E. pectinalis* var. *ventralis* (Ehrenb.) Hust.
41
Eunotia perpusilla Grun.
42
Eunotia praerupta Ehrenb.
20, 21, 27, 28, 29, 41, 97, 98, 99, 116, 121, 124, 125, 126
=*E. praerupta* var. *genuina* Grun.
119
Eunotia praerupta var. *bidens* (Ehrenb.) Grun.
30, 41, 124
Eunotia praerupta var. *inflata* Grun.
29, 98, 99, 124, 125, 126
Eunotia rostellata Hust. ex Patr.
20, 21, 29, 99, 124
Eunotia septentrionalis Østr.
41, 124, 125
Eunotia serra Ehrenb.
20, 21, 29, 42, 76, 77, 98, 99, 110, 112, 117, 124, 125, 126
=*E. robusta* Ralfs
2, 29, 32, 99, 100, 124, 125
Eunotia serra var. *diadema* (Ehrenb.) Patr.
20, 21, 29, 31, 98, 99, 124, 125, 126
=*E. robusta* var. *diadema* (Ehrenb.) Ralfs
41
=*E. tetraodon* Ehrenb.
2
=*E. robusta* var. *tetraodon* (Ehrenb.) Ralfs
97, 124
=*E. serrulata* Ehrenb.
2
Eunotia sudetica O. Müll.
29, 99, 124
Eunotia suecica A. Cleve
20, 21, 124
Eunotia tenella (Grun.) A. Cleve
29, 41, 98, 99, 111, 119, 124
Eunotia tridentula Ehrenb.
27, 28
=*E. perpusilla* var. *perminuta* (Grun.) Ross
119
=*E. polydentula* (Brun) Hust.
41
Eunotia tridentula var. *bidentula* Å. Berg
27, 28
Eunotia triodon Ehrenb.
2, 97, 99, 103, 117, 119, 124, 126
Eunotia valida Hust.
20, 21, 27, 28, 29, 77, 99, 121, 124
Eunotia vanheurckii Patr.
20, 21, 29, 41, 99, 121, 124, 126
=*E. faba* (Ehrenb.) Grun.
41, 103, 124
Eunotia vanheurckii var. *intermedia* (Krasske ex Hust.) Patr.
20, 21, 29, 41, 98, 99, 124
Eunotia vanheurckii var. *intermedia* f. *rhomboica* Foged
41
Eunotia veneris (Kütz.) De Toni
100, 124
Eunotia zasuminensis (Cabejsz.) Körner
=*Fragilaria zasuminensis* Cabejsz.
5
Eunotia spp.
22, 29, 39, 41, 42, 87, 99, 106, 110, 112, 116, 117, 118, 121, 124, 125, 126
Peronia fibula (Bréb. ex Kütz.) Ross
41
Peronia sp.
=*Peroniopsis* sp.
124
Semiorbis hemicyclus (Ehrenb.) Patr.
20, 21, 29, 98, 99, 124
=*Amphicampa hemicyclus* (Ehrenb.) Karsten
124

Achnanthales

Achnanthes austriaca Hust.
41
Achnanthes austriaca var. *helvetica* Hust.
41
Achnanthes boyeri McKay
2
Achnanthes calcar Cleve
103
Achnanthes clevei Grun.
105
Achnanthes exigua Grun.
124, 125
Achnanthes flexella (Kütz.) Brun
27, 28, 33, 103, 111, 116, 124, 125, 126
Achnanthes inflata (Kütz.) Grun.
99, 116, 117, 124
Achnanthes kryophila Petersen
41
Achnanthes lanceolata (Bréb. ex Kütz.) Grun.
1, 27, 28, 30, 31, 88, 98, 105, 111, 116, 121, 124, 125, 126

Achnanthes lanceolata var. *elliptica* Cleve
103
Achnanthes levanderi Hust.
41
Achnanthes marginulata Grun.
29, 41, 99 (*A. marginata*), 103, 119, 124 (aussi sous *A. marginata*)
Achnanthes minutissima Kütz.
27, 28, 29, 30, 42, 98, 99, 103, 105, 111, 121, 124, 126
=*A. affinis* Grun.
30, 121
=*A. linearis* (W. Sm.) Grun.
41, 76, 103, 107, 121, 124
=*A. linearis* f. *curta* H.L. Sm. ex Boyer
30, 121
=*A. microcephala* (Kütz.) Cleve
116, 124
=*A. minutissima* var. *cryptocephala* Grun.
119
Achnanthes nodosa Cleve-Euler
41
Achnanthes obliqua (Greg.) Hust.
103
Achnanthes peragalli Brun & Hérib.
103
Achnanthes pinnata Hust.
121
Achnanthes pusilla Grun.
=*A. linearis* var. *pusilla* (Grun.) Cleve
121
Achnanthes quadratarea (Østr.) Ross
=*A. lapponica* (Hust.) Hust.
41, 103
Achnanthes quadratarea var. *fennica* (Cleve-Euler) Ross
=*A. lapponica* var. *fennica* Cleve-Euler
31
Achnanthes recurvata Hust.
41
Achnanthes rostrata Østr.
=*A. lanceolata* var. *rostrata* (Østr.) Hust.
111
=*A. lanceolata* var. *dubia* Grun.
30, 121
Achnanthes saxonica Krasske
42, 124, 125
Achnanthes stewartii Patr.
1, 88
Achnanthes spp.
20, 29, 41, 76, 99, 116, 117, 118, 124, 125, 126
Cocconeis diminuta Pant.
103
Cocconeis disculus (Schumann) Cleve
30, 121
Cocconeis fluviatilis Wallace
30, 121, 124, 125, 126
Cocconeis pediculus Ehrenb.
30, 97, 121
Cocconeis placentula Ehrenb.
1, 22, 24, 25, 29, 30, 33, 39, 88, 97, 99, 105, 111, 121, 124, 125, 126
Cocconeis placentula var. *euglypta* (Ehrenb.) Grun.
30, 121
Cocconeis placentula var. *lineata* (Ehrenb.) V.H.
30, 103, 121
Cocconeis rugosa Sov.
20, 21, 121
Cocconeis spp.
3, 22, 23, 29, 76, 95, 99, 121, 124, 125, 126

Bacillariales

Bacillaria paxillifer (O.F. Müll.) Hendey
=*B. paradoxa* Gmelin
27, 28, 29, 88, 97, 98, 99, 121, 124
Denticula tenuis var. *intermedia* Grun.
119
Hantzschia amphioxys (Ehrenb.) Grun.
1, 2, 3, 27, 28, 30, 41, 88, 97, 121
=*Nitzschia amphioxys* (Ehrenb.) W. Sm.
2
Hantzschia amphioxys var. *vivax* Grun.
27, 28
Hantzschia elongata (Hantzsch) Grun.
3
Hantzschia spectabilis (Ehrenb.) Hust.
=*Nitzschia spectabilis* (Ehrenb.) Ralfs
2, 3
Hantzschia virgata (Roper) Grun.
2
Hantzschia sp.
39
Nitzschia acicularis (Kütz.) W. Sm.
1, 27, 28, 29, 30, 88, 95, 98, 99, 105, 111, 116, 121, 124, 125, 126
Nitzschia acicularis var. *closterioides* Grun.
116, 124
Nitzschia actinastroides (Lemm.) Van Goor
24, 25, 29, 88, 99, 116, 124
=*Synedra actinastroides* Lemm.
20, 21, 121, 124, 125
Nitzschia acula Hantzsch ex Cleve & Grun.
29 (*N. acuta*), 88 (*N. acuta*), 98 (*N. acuta*), 99 (*N. acuta*), 121 (*N. acuta*), 124 (*N. acuta*)
=*N. dissipata* var. *acuta* (Hantzsch ex Cleve & Grun.) V.H.
30 (var. *acuta*), 121 (var. *acuta*)
Nitzschia amphibia Grun.
1, 27, 28, 29, 30, 88, 98, 99, 105, 111, 119, 121, 124, 126
Nitzschia clausii Hantzsch
121
Nitzschia commutata Grun.
24, 25, 30, 88, 121
Nitzschia dissipata (Kütz.) Grun.
1, 24, 25, 29, 30, 88, 98, 99, 105, 111, 121, 124, 125
Nitzschia dissipata var. *media* (Hantzsch) Grun.
30, 121

Nitzschia filiformis (W. Sm.) V.H.
27, 28, 29, 30, 99, 121, 124
Nitzschia flexa Schumann
121
Nitzschia fonticola Grun.
30, 121
Nitzschia franconica Reinsch
20, 21, 99, 116, 117, 124, 125, 126
Nitzschia frustulum (Kütz.) Grun.
30, 103, 119, 121, 124
Nitzschia gracilis Hantzsch
29, 98, 99, 124
Nitzschia hantzschiana Rabenh.
2, 111
Nitzschia heufleriana Grun.
2
Nitzschia homburgiensis Lange-Bertalot
=*N. thermalis* (Ehrenb.) Auersw. ex Rabenh.
30, 121
=*N. thermalis* var. *minor* Hilse
121
Nitzschia ignorata Krasske
29, 99, 124
Nitzschia intermedia Hantzsch ex Cleve & Grun.
2, 105
Nitzschia kuetzingiana Hilse
121
Nitzschia linearis W. Sm.
2, 24, 25, 88, 105, 111, 121
Nitzschia lorenziana var. *subtilis* Grun.
29, 98, 99, 121, 124
Nitzschia microcephala Grun.
121
Nitzschia minutula Grun.
30, 121
Nitzschia nyassensis O. Müll.
121
Nitzschia obtusa W. Sm.
1, 20, 21, 29, 88, 98, 99, 105, 117, 124, 125
Nitzschia palea (Kütz.) W. Sm.
1, 2, 27, 28, 29, 30, 33, 88, 98, 99, 109, 110, 111, 112, 121, 124
Nitzschia paleacea (Grun.) Grun.
29, 30, 88, 99, 121, 124
=*N. holsatica* Hust.
1, 30, 88, 98, 116, 121, 124, 125, 126
Nitzschia perminuta (Grun.) M. Perag.
41
Nitzschia pseudoamphioxys Hust.
27, 28, 124
Nitzschia recta Hantzsch ex Rabenh.
103, 110, 111, 112, 121
Nitzschia sigma (Kütz.) W. Sm.
1, 2, 26, 29, 30, 88, 97, 99, 121, 124
Nitzschia sigmoidea (Nitzsch) W. Sm.
1, 2, 3, 24, 25, 29, 30, 39, 88, 95, 97, 98, 99, 116, 121, 124
Nitzschia sublinearis Hust.
29, 99, 121, 124
Nitzschia tenuis W. Sm.
2
=*N. subtilis* Grun.
33, 121
Nitzschia umbonata (Ehrenb.) Lange-Bertalot
=*N. stagnorum* Rabenh.
2, 111
Nitzschia vermicularis (Kütz.) Hantzsch
2, 3, 24, 25, 29, 88, 98, 99, 100, 121, 124
Nitzschia vitrea Norman
29, 99, 124
Nitzschia vitrea var. *major* Cleve
98
Nitzschia spp.
1, 3, 20, 22, 23, 29, 39, 99, 106, 116, 117, 121, 124, 125, 126
Tryblionella angustata W. Sm.
=*Nitzschia angustata* (W. Sm.) Grun.
24, 25, 88, 98, 103, 121
Tryblionella apiculata Greg.
=*Nitzschia apiculata* (Greg.) Grun.
121
Tryblionella balatonis (Grun.) Mann
=*Nitzschia balatonis* Grun.
2
Tryblionella debilis Arnott
=*Nitzschia tryblionella* var. *debilis* (Arnott) Hust.
121
Tryblionella gracilis W. Sm.
=*T. hantzschiana* Grun.
97
Tryblionella hungarica (Grun.) Mann
=*Nitzschia hungarica* Grun.
1, 2, 3, 88, 98, 121, 124
Tryblionella levidensis W. Sm.
=*Nitzschia tryblionella* var. *levidensis* (W. Sm.) Grun.
30, 121
Tryblionella littoralis (Grun.) Mann
=*Nitzschia littoralis* Grun.
31, 32
Tryblionella navicularis (Bréb. ex Kütz.) Ralfs
=*Nitzschia navicularis* (Bréb. ex Kütz.) Grun.
1, 88

Cymbellales

Anomoeoneis sphaerophora (Ehrenb.) Pfitzer
1, 88, 124
Cymbella aequalis W. Sm. ex Grev.
119
Cymbella affinis Kütz.
27, 28, 29, 30, 99, 110, 111, 112, 121, 124
Cymbella amphicephala Näg. ex Kütz.
41, 121, 124, 126
Cymbella angustata var. *hybrida* (Grun. ex A. Schmidt) Ross
119
Cymbella aspera (Ehrenb.) H. Perag.
2, 20, 21, 92, 116, 121, 124, 125

=*C. gastroides* (Kütz.) Kütz.
2, 97
Cymbella aspera var. *minor* (V.H.) Cleve
=*C. gastroides* var. *minor* V.H.
97
Cymbella austriaca Grun.
29, 99, 124
Cymbella botellus (Lagerst.) A. Schmidt
119
Cymbella cesatii (Rabenh.) Grun.
29, 41, 99, 103, 124
Cymbella cistula (Ehrenb.) Kirchn.
1, 2, 20, 21, 29, 88, 98, 99, 103, 105, 116, 121, 124, 125, 126
Cymbella cistula var. *maculata* (Kütz.) V.H.
116, 124
=*C. maculata* (Kütz.) Bréb. & Godey
2
Cymbella cornuta (Ehrenb.) Ross
=*C. lanceolata* Kirchn.
2, 3, 103, 111, 121
Cymbella cuspidata Kütz.
2, 20, 21, 30, 103, 121, 124, 126
Cymbella cymbiformis C. Ag.
2, 29, 99, 121, 124
Cymbella diluviana (Krasske) Florin
121
Cymbella gaeumanni Meister
41
Cymbella gracilis (Ehrenb.) Kütz.
2, 20, 21, 111
Cymbella hebridica (Grun. ex Cleve) Cleve
41
Cymbella heteropleura (Ehrenb.) Kütz.
2
Cymbella hustedtii Krasske
41
Cymbella inaequalis (Ehrenb.) Rabenh.
20
=*C. ehrenbergii* Kütz.
21, 124
=*C. ehrenbergii* var. *typica* Cleve-Euler
27, 28
Cymbella lacustris (C. Ag.) Cleve
29, 98, 99, 124
Cymbella laevis Näg. ex Kütz.
29, 99, 124
Cymbella lunata W. Sm.
121, 124, 126
Cymbella mexicana (Ehrenb.) Cleve
30, 121
Cymbella microcephala Grun.
103, 119, 121
Cymbella minuta Hilse ex Rabenh.
121, 124, 126
=*C. ventricosa* Kütz.
1, 21, 24, 25, 27, 28, 30, 98, 99, 103, 105, 111, 124, 125, 126
=*Encyonema ventricosum* (Kütz.) Grun.
2
Cymbella minuta f. *latens* (Krasske) Reimer
121 (var. *latens*)
Cymbella minuta var. *pseudogracilis* (Cholnoky) Reimer
121
Cymbella minuta var. *silesiaca* (Bleisch ex Rabenh.) Reimer
121
Cymbella naviculiformis Auersw. ex Heib.
27, 28, 29, 98, 99, 100, 111, 124, 126
=*C. cuspidata* var. *anglica* (Lagerst.) Cleve-Euler
1, 88, 124
Cymbella norvegica Grun.
121
Cymbella ovalis Bréb.
124
Cymbella parva (W. Sm.) Kirchn.
24, 25, 88
Cymbella prostrata (Berk.) Brun
1, 20, 24, 25, 30, 88, 98, 105, 121, 124
=*Encyonema prostratum* (Berk.) Kütz.
2, 3
Cymbella prostrata var. *auerswaldii* (Rabenh.) Reimer
121
=*C. caespitosa* (Kütz.) Brun
33
Cymbella pusilla Grun. ex A. Schmidt
27, 28, 29, 99, 124
Cymbella radiosa Reich.
29, 99, 124
Cymbella scotica var. *incerta*[22](Cleve) Ross
119
Cymbella sinuata Greg.
30, 105, 121
Cymbella stauroneiformis Lagerst.
119
Cymbella stuxbergii (Cleve) Cleve
32
Cymbella subaequalis Grun.
121
Cymbella subcuspidata Krammer
=*C. heteropleura* var. *minor* Cleve
119
Cymbella tumida (Bréb. ex Kütz.) Grun.
2, 29, 99, 121, 124
Cymbella tumida var. *gracilis* Hust.
29, 99, 124
Cymbella tumidula Grun. ex A. Schmidt
29, 99, 124
Cymbella turgida Greg.
20, 21, 29, 98, 99, 117, 124, 126
Cymbella turgidula Grun.
105, 116, 121, 124, 125
=*C. ventricosa* (C. Ag.) C. Ag.
20, 29, 88, 116

Cymbella spp.
20, 29, 39, 82, 92, 95, 99, 111, 124, 125, 126
Didymosphenia geminata (Lyngb.) M. Schmidt
124
=*Gomphonema geminatum* (Lyngb.) C. Ag.
2, 97, 101
Gomphoneis elegans (Grun.) Cleve
=*Gomphonema elegans* Grun.
124
Gomphoneis herculeana (Ehrenb.) Cleve
3, 24, 25, 30, 88, 121, 124
Gomphoneis herculeana var. *robusta* (Grun.) Cleve
121
Gomphoneis herculeana var. *septiceps* M. Schmidt
121
Gomphoneis olivacea (Hornemann) Dawson ex Ross & Sims
=*Gomphonema olivaceum* (Hornemann) Bréb.
1, 24, 25, 27, 28, 29, 30, 88, 98, 99, 105, 111, 116, 121, 124
***Gomphoneis olivacea* var. *calcarea* (Cleve) Poulin, comb. nov.**
Basionyme: *Gomphonema calcareum* Cleve 1868, p. 231, pl. 4, fig. 7-9.
=*Gomphonema olivaceum* var. *calcarea* (Cleve) V.H.
121
Gomphonema acuminatum Ehrenb.
2, 20, 30, 90 (*G. aculeatum*), 92, 97, 105, 111, 116, 121, 124
=*G. acuminatum* var. *laticeps* (Ehrenb.) Grun.
103
Gomphonema acuminatum var. *brebissonii* (Kütz.) Schönf.
21
Gomphonema acuminatum var. *coronatum* (Ehrenb.) W. Sm.
20, 21, 27, 28, 29, 97, 98, 99, 111, 117, 124, 125, 126
Gomphonema affine var. *insigne* (Greg.) Andrews
121
Gomphonema angustatum (Kütz.) Rabenh.
42, 111, 121
Gomphonema angustatum var. *obtusatum* (Kütz.) Grun.
41
Gomphonema augur Ehrenb.
1, 30, 88, 98, 121
Gomphonema auritum A. Br. ex Kütz.
20
=*G. longiceps* var. *subclavatum* Grun.
24, 25, 88
=*G. subclavatum* (Grun.) Grun.
121
=*G. longiceps* var. *subclavatum* f. *gracile* Hust.
21, 124 (*G. longiceps* f. *gracile*)
Gomphonema carolinense Hagelstein
121
Gomphonema fusus Fricke
29, 99, 124
Gomphonema gracile Ehrenb.
20, 103, 121
Gomphonema grunowii Patr.
121
=*G. lanceolatum* Ehrenb.
30, 121, 124, 125, 126
=*G. gracile* var. *lanceolatum* Cleve
21
Gomphonema hedinii Hust.
121
Gomphonema longiceps Ehrenb.
=*G. mustela* Ehrenb.
119
Gomphonema majus Cleve-Euler
105
Gomphonema montanum Schumann
=*G. longiceps* var. *montanum* (Schumann) Hust.
27, 28
Gomphonema parvulum (Kütz.) Kütz.
30, 41, 105, 111, 121, 124
Gomphonema parvulum var. *exilissimum* Grun.
28
Gomphonema parvulum var. *micropus* (Kütz.) Cleve
=*G. micropus* Kütz.
119
Gomphonema simus Hohn & Hellerman
121
Gomphonema sphaerophorum Ehrenb.
29, 99, 124
Gomphonema subtile Ehrenb.
20, 21, 124
Gomphonema tenellum Kütz.
121
Gomphonema truncatum Ehrenb.
20, 121
=*G. constrictum* Ehrenb. ex Kütz.
2, 21, 24, 25, 29, 88, 97, 99, 101, 103, 111, 124, 125, 126
Gomphonema truncatum var. *capitatum* (Ehrenb.) Patr.
20, 121
=*G. capitatum* Ehrenb.
2, 100, 111
=*G. constrictum* var. *capitatum* (Ehrenb.) V.H.
21, 97, 103
Gomphonema ventricosum Greg.
30, 121
Gomphonema vibrio var. *intricatum* (Kütz.) Ross
=*G. intricatum* Kütz.
103, 121, 124
Gomphonema vibrio var. *pumilum* (Grun.) Ross
=*G. intricatum* var. *pumilum* Grun.
103, 121
Gomphonema spp.
20, 22, 23, 29, 39, 78, 82, 94, 95, 99, 103, 116, 121, 124, 125, 126

Rhoicosphenia abbreviata (C. Ag.) Lange-Bertalot
=*R. curvata* (Kütz.) Grun.
1, 24, 25, 30, 88, 98, 105, 111, 121
=*Gomphonema abbreviatum* C. Ag.
121
Rhoicosphenia sp.
76

Lyrellales

Lyrella irrorata (Grev.) Mann
=*Navicula irrorata* Grev.
100

Mastogloiales

Aneumastus tusculus (Ehrenb.) Mann & Stickle
=*Navicula tuscula* Ehrenb.
24, 25, 111, 124

Naviculales

Amphipleura pellucida (Kütz.) Kütz.
24, 25, 29, 31, 32, 33, 88, 98, 99, 124
Amphipleura spp.
39, 116, 124, 125, 126
Brachysira follis (Ehrenb.) Ross
=*Anomoeoneis follis* (Ehrenb.) Cleve
124
Brachysira microcephala (Grun.) Compère
=*Anomoeoneis exilis* (Kütz.) Cleve
41
=*Anomoeoneis vitrea* (Grun.) Ross
41, 103
=*Navicula variabilis* var. *gomphonemacea* (Grun.) Ross
119
Brachysira serians (Bréb. ex Kütz.) Round & Mann
20
=*Anomoeoneis serians* (Bréb. ex Kütz.) Cleve
21, 42, 103, 124, 125
***Brachysira zellensis* var. *linearis* (Østr.) Poulin, comb. nov.**
Basionyme: *Anomoeoneis zellensis* var. *linearis* Østrup 1910, p. 239, pl. 14, fig. 6.
=*Navicula zellensis* var. *linearis* (Østr.) Ross
119
Caloneis amphisbaena (Bory) Cleve
116, 124
Caloneis bacillum (Grun.) Cleve
30, 103, 121
Caloneis limosa (Kütz.) Patr.
=*Navicula limosa* Kütz.
97
?*Caloneis silicula* ssp. *limosa* var. *biconstricta* (Østr.) Cleve-Euler
27, 28
Caloneis ventricosa (Ehrenb.) Meister
=*C. silicula* (Ehrenb.) Cleve
24, 25, 88
Caloneis ventricosa var. *truncatula* (Grun.) Meister
27, 28, 29, 99, 121, 124
Caloneis spp.
29, 39, 124

Cavinula cocconeiformis (Greg. ex Grev.) Mann & Stickle
=*Navicula cocconeiformis* Greg. ex Grev.
41, 111
Cavinula lacustris (Greg.) Mann & Stickle
=*Navicula lacustris* Greg.
29, 98, 99, 124
Cavinula pseudoscutiformis (Hust.) Mann & Stickle
=*Navicula pseudoscutiformis* Hust.
41, 103
Cavinula scutiformis (Grun. ex A. Schmidt) Mann & Stickle
=*Navicula scutiformis* Grun. ex A. Schmidt
103
Cosmioneis pusilla (W. Sm.) Mann & Stickle
=*Navicula pusilla* W. Sm.
1, 88
Craticula ambigua (Kütz.) Mann
=*Navicula cuspidata* var. *ambigua* (Ehrenb.) Cleve
100
Craticula cuspidata (Kütz.) Mann
=*Navicula cuspidata* (Kütz.) Kütz.
1, 2, 20, 21, 29, 30, 41, 88, 98, 99, 111, 121, 124
Craticula halophila (Grun. ex V.H.) Mann
=*Navicula halophila* (Grun. ex V.H.) Cleve
2, 41
Diadesmis confervacea Kütz.
=*Navicula confervacea* (Kütz.) Grun.
1, 88
Diadesmis contenta (Grun. ex V.H.) Mann
=*Navicula contenta* Grun. ex V.H.
41
***Diadesmis contenta* var. *parallela* (Petersen) Hamilton, comb. nov.**
Basionyme: *Navicula contenta* var. *parallela* Petersen 1928, p. 15, fig. 2
119
Diadesmis perpusilla (Kütz.) Mann
=*Navicula perpusilla* (Kütz.) Grun.
29, 99, 124
Diatomella hustedtii Manguin
124
Diploneis elliptica (Kütz.) Cleve
98, 121
=*Navicula ovalis* W. Sm.
2
Diploneis finnica (Ehrenb.) Cleve
27, 28, 30, 121
Diploneis oblongella (Näg. ex Kütz.) Ross
27, 28, 29, 98, 99, 124
=*D. ovalis* var. *oblongella* (Näg. ex Kütz.) Cleve
32
Diploneis ovalis (Hilse) Cleve
103, 124, 125, 126
=*D. oblongella* var. *ovalis* (Hilse) Ross
119

Diploneis pseudovalis Hust.
121, 124, 125
Diploneis puella (Schumann) Cleve
121
Diploneis smithii (Bréb. ex W. Sm.) Cleve
1, 31, 32, 88, 98, 124, 125, 126
=*Navicula elliptica* W. Sm.
2
Diploneis spp.
29, 95, 99, 124, 125, 126
Fallacia indifferens (Hust.) Mann
=*Navicula indifferens* Hust.
41
Frustulia amphipleuroides (Grun.) Cleve-Euler
=*F. rhomboides* var. *amphipleuroides* (Grun.) De Toni
3, 29, 99, 124
Frustulia rhomboides (Ehrenb.) De Toni
20, 21, 24, 25, 29, 30, 32, 41, 42, 76, 77, 87, 88, 98, 99, 103, 109, 110, 111, 112, 116, 117, 121, 124, 125, 126
=*Vanheurckia rhomboides* (Ehrenb.) Bréb.
97
Frustulia rhomboides f. *capitata* (Mayer) Hust.
=*F. rhomboides* var. *capitata* (Mayer) Patr.
20, 21, 29, 98, 99, 124, 125, 126
Frustulia rhomboides var. *crassinervia* (Bréb. ex W. Sm.) Ross
27, 28, 29, 30, 99, 116, 119, 121, 124, 126
=*Vanheurckia crassinervia* (Bréb. ex W. Sm.) Bréb.
2
Frustulia rhomboides var. *saxonica* (Rabenh.) De Toni
20, 21, 27, 28, 29, 41, 99, 103, 107, 111, 121, 124, 125, 126
Frustulia rhomboides var. *viridula* (Bréb. ex Kütz.) Cleve
=*Vanheurckia viridula* (Bréb. ex Kütz.) Bréb.
97
Frustulia vulgaris (Thwaites) De Toni
24, 25, 27, 28, 88
=*Vanheurckia vulgaris* (Thwaites) V.H.
2
Frustulia weinholdii Hust.
121 (*F. rhomboides* var. *weinholdii*)
Frustulia spp.
20, 29, 82, 87, 99, 124, 125, 126
Gyrosigma acuminatum (Kütz.) Rabenh.
1, 29, 76 (?*Pinnularia acuminatum*), 88, 98, 99, 105, 111, 124
=*Pleurosigma acuminatum* (Kütz.) W. Sm.
2, 3
Gyrosigma attenuatum (Kütz.) Rabenh.
1, 24, 25, 30, 88, 90, 92, 103, 105, 111, 121, 124
=*Pleurosigma attenuatum* (Kütz.) W. Sm.
2, 3, 97
Gyrosigma obscurum (W. Sm.) Griff. & Henfrey
1, 88, 98
Gyrosigma obtusatum (Sullivant & Wormley) Boyer
30, 121
Gyrosigma scalproides (Rabenh.) Cleve
24, 25, 88
Gyrosigma spenceri (Quek.) Griff. & Henfrey
24, 25, 88, 103
Gyrosigma spenceri var. *exile* (Grun.) Cleve
=*G. exile* (Grun.) Reimer
1, 88
Gyrosigma spenceri var. *nodiferum* (Grun.) Cleve
=*G. nodiferum* (Grun.) G. West
30, 98, 121
Gyrosigma wormleyi (Sullivant) Boyer
1, 30, 88, 98, 121
Gyrosigma spp.
20, 39, 76, 95, 116, 124, 125, 126
Luticola cohnii (Hilse) Mann
=*Navicula mutica* var. *cohnii* (Hilse) Grun.
29, 30, 99, 121
Luticola mutica (Kütz.) Mann
=*Navicula mutica* Kütz.
29, 99, 121, 124
=*Navicula rotaeana* (Rabenh.) Grun.
119
Luticola undulata (Hilse) Mann
=*Navicula mutica* var. *undulata* (Hilse) Grun.
30, 121
Navicula anglica Ralfs
24, 25, 88, 105, 111
Navicula anglica var. *subsalsa* (Grun.) Cleve
29, 98, 99, 124
Navicula angusta Grun.
1, 29, 88, 99, 124
Navicula arvensis Hust.
30, 121
Navicula atomus (Kütz.) Grun.
2
Navicula aurora Sov.
1, 29, 33, 88, 99, 124
Navicula bicephala Hust.
29, 99, 124
Navicula bilobata Leuduger-Fortmorel
2
Navicula capitata Ehrenb.
27, 28, 30, 105, 121, 124, 125, 126
=*N. hungarica* var. *capitata* (Ehrenb.) Cleve
111
=*N. humilis* Donk.
100
Navicula capitata var. *hungarica* (Grun.) Ross
27, 28
=*N. hungarica* var. *linearis* Østr.
111
Navicula cincta (Ehrenb.) Ralfs
105, 111, 121
Navicula crucicula (W. Sm.) Donk.
=*Stauroneis crucicula* W. Sm.
99, 117, 124

Navicula cryptocephala Kütz.
1, 2, 3, 27, 28, 29, 88, 98, 99, 103, 105, 109, 110, 111, 112, 116, 121, 124, 125
Navicula cryptocephala var. *exilis* (Kütz.) Grun.
29, 99, 124
Navicula cryptocephala var. *veneta* (Kütz.) Rabenh.
29, 30, 99, 121, 124
?*Navicula cuspidata* var. *heribaudii* M. Perag.
=*Surirella craticula* Ehrenb.
2
?*Navicula cuspidata* var. *major* Meister
1, 88
Navicula dicephala Ehrenb.
2, 111
Navicula elginensis (Greg.) Ralfs
27, 28, 30, 121, 124
Navicula elginensis var. *lata* (M. Perag.) Patr.
29, 99
Navicula elginensis var. *rostrata* (Mayer) Patr.
30, 121, 124
Navicula exigua Grun.
27, 28, 30, 32, 111, 121, 124
=*N. exigua* var. *capitata* Patr.
124, 126
Navicula explanata Hust.
29, 30, 99, 121, 124
Navicula festiva Krasske
41
Navicula galikii (Pant.) Cleve
=*N. amphibola* Cleve
1, 24, 25, 88, 105, 124
Navicula globulifera Hust.
1, 88, 124
Navicula gottlandica Grun.
111
Navicula graciloides Mayer
33, 105, 121
Navicula grimmei Krasske
27, 28
Navicula hambergii Hust.
30, 121
Navicula hilliardii Manguin
41
Navicula heufleri Grun.
30, 121
Navicula heufleri var. *leptocephala* (Bréb., Kütz. ex Grun.) H. & M. Perag.
121
Navicula lanceolata (C. Ag.) Kütz.
29, 30, 33, 99, 121, 124
Navicula latens Krasske ex Hust.
121
Navicula lateropunctata Wallace
121
Navicula longa (Greg.) Ralfs
2
Navicula menisculus var. *upsaliensis* Grun.
121
Navicula minima Grun.
29, 99, 111, 124, 125, 126
Navicula minnewaukonensis Elmore
121
Navicula minuscula Grun.
1, 88
Navicula notha Wallace
27, 28, 29, 99, 124
Navicula pelliculosa (Kütz.) Hilse
30, 121
Navicula peregrina (Ehrenb.) Kütz.
1, 30, 88, 98, 105, 121, 124
Navicula placenta Ehrenb.
124
Navicula placentula (Ehrenb.) Kütz.
30, 111, 121
Navicula protracta Grun.
29, 98, 99, 121, 124
Navicula protracta f. *subcapitata* (Wislouch & Poretsky) Hust.
41
Navicula pseudoreinhardtii Patr.
121
Navicula radiosa Kütz.
1, 2, 25, 27, 28, 29, 30, 31, 33, 42, 88, 98, 99, 103, 105, 111, 121, 124
Navicula radiosa var. *acuta* (W. Sm.) Grun.
=*Pinnularia acuta* W. Sm.
124
Navicula radiosa var. *parva* Wallace
29, 30, 121, 124
Navicula radiosa var. *tenella* (Bréb. ex Kütz.) Grun.
27, 28, 29, 99, 103, 121, 124
=*N. tenella* Bréb. ex Kütz.
2
Navicula reinhardtii Grun.
1, 2, 88, 98, 121
Navicula rhynchocephala Kütz.
1, 2, 29, 32, 88, 99, 111, 121, 124, 126
Navicula rhynchocephala var. *germainii* (Wallace) Patr.
29, 99, 124
Navicula salinarum[(23)] Grun.
29, 99, 121, 124
Navicula salinarum var. *intermedia* (Grun.) Cleve
30, 121
Navicula schassmannii Hust.
41
Navicula scutelloides W. Sm. ex Greg.
2, 30, 105, 121, 124
Navicula semen Ehrenb.
124
Navicula soehrensis Krasske
41
Navicula soehrensis var. *hassiaca* (Krasske) Lange-Bertalot
41
Navicula subtilissima Cleve
29, 99, 119, 124, 125, 126

Navicula symmetrica Patr.
30, 121
Navicula tripunctata (O.F. Müll.) Bory
1, 30, 88, 121
=*N. gracilis* Ehrenb.
24, 25, 88
Navicula tripunctata var. *schizonemoides* (V.H.) Patr.
29, 30, 99, 121, 124
Navicula viridula (Kütz.) Ehrenb.
1, 2, 30, 88, 105, 111, 121
Navicula viridula var. *linearis* Hust.
99, 117, 124
Navicula viridula var. *rostellata* (Kütz.) Cleve
29, 98, 99, 124
=*N. rostellata* Kütz.
3
Navicula vulpina Kütz.
1, 29, 32, 88, 98, 99, 124
Navicula spp.
1, 3, 20, 22, 23, 29, 39, 41, 76, 87, 90, 92, 95, 99, 101, 106, 109, 110, 112, 116, 117, 118, 121, 124, 125, 126
Neidium affine (Ehrenb.) Pfitzer
1, 29, 88, 98, 99, 103, 124
Neidium affine var. *amphirhynchus* (Ehrenb.) Cleve
=*Navicula amphirhynchus* Ehrenb.
2
Neidium affine var. *undulatum* (Grun.) Cleve
27, 28
Neidium affine var. *undulatum* f. *constrictum* (Krasske) Cleve-Euler
27, 28
Neidium ampliatum (Ehrenb.) Krammer
=*N. iridis* var. *ampliatum* (Ehrenb.) Cleve
29, 99, 119, 124
Neidium apiculatum var. *constrictum* Reimer
29, 99, 124
Neidium bisulcatum (Lagerst.) Cleve
29, 41, 99, 119, 124
Neidium bisulcatum f. *undulatum* (O. Müll) Hust.
27, 28
Neidium bisulcatum var. *baicalense* (Skvortzow & Meyer) Reimer
29, 99, 124
Neidium dubium (Ehrenb.) Cleve
1, 29, 30, 77, 88, 99, 109, 121, 124
=*Navicula iridis* var. *dubium* (Ehrenb.) V.H.
97
Neidium dubium f. *constrictum* (Hust.) Hust.
29, 99, 124
Neidium hitchcockii (Ehrenb.) Cleve
20, 21, 124
=*Navicula hitchcockii* Ehrenb.
2
Neidium inconspicuum Hust.
20
Neidium iridis (Ehrenb.) Cleve
20, 21, 29, 33, 41, 99, 103, 124
=*Navicula iridis* Ehrenb.
2, 97
=*Navicula firma* Kütz.
2
Neidium iridis f. *vernale* Reich. ex Hust.
41
Neidium iridis var. *amphigomphus* (Ehrenb.) Mayer
20, 21, 29, 98, 99, 124
Neidium sacoense Reimer
20, 21
Neidium temperei Reimer
29, 99, 124
Neidium spp.
20, 29, 39, 103, 124, 125, 126
Pinnularia abaujensis (Pant.) Ross
20, 21, 29, 99, 124
Pinnularia abaujensis var. *linearis* (Hust.) Patr.
121
Pinnularia abaujensis var. *subundulata* (Mayer ex Hust.) Patr.
29, 98, 99, 121, 124
Pinnularia acrosphaeria W. Sm.
1, 29, 88, 99, 100, 124
Pinnularia aestuarii Cleve
31, 32
Pinnularia appendiculata (C. Ag.) Cleve
29, 99, 124
Pinnularia bicapitata (Lagerst.) Cleve
=*Navicula bicapitata* Lagerst.
2
Pinnularia biceps Greg.
20, 21, 27, 28, 29, 98, 99, 124
=*P. biceps* f. *biceps* (Cleve) Ross
119
Pinnularia borealis Ehrenb.
30, 41, 100, 119, 121
Pinnularia boyeri Patr.
20, 21
Pinnularia brauniana (Grun. ex A. Schmidt) Mills
=*P. braunii* (Grun. ex A. Schmidt) Cleve
124
=*Navicula braunii* [(24)]Grun.
2
Pinnularia brevicostata Cleve
124
Pinnularia cardinalis (Ehrenb.) W. Sm.
124
Pinnularia caudata (Boyer) Patr.
29, 99, 124
Pinnularia commutata (Grun. ex A. Schmidt) Dippel
=*Navicula commutata* Grun. ex A. Schmidt
2
=*P. viridis* var. *commutata* (Grun. ex A. Schmidt) Cleve
30
Pinnularia cruciata (Cleve) Cleve
=*Navicula cruciata* Cleve
2

Pinnularia dactylus Ehrenb.
20, 21, 24, 25, 29, 32, 82, 88, 99, 100, 116, 124, 126
=*Navicula dactylus* (Ehrenb.) Kütz.
2
Pinnularia divergens W. Sm.
20, 21, 29, 31, 32, 99, 121, 124, 126
=*P. divergens* var. *genuina* Meister
119
Pinnularia divergens var. *elliptica* (Grun.) Cleve
29, 124
Pinnularia divergentissima var. *hustedtiana* Ross
119
Pinnularia gentilis (Donk.) Cleve
29, 99, 100, 124
Pinnularia globiceps var. *krookii* (Grun.) Cleve
119
Pinnularia hudsonensis Ross
119
Pinnularia intermedia (Lagerst.) Cleve
29, 98, 99, 124
Pinnularia lata (Bréb.) W. Sm.
30, 41, 100, 116, 121, 124
Pinnularia latevittata var. *domingensis* Cleve
121, 124
Pinnularia legumen Ehrenb.
20, 21, 29, 98, 99, 124
Pinnularia mayeri Krammer
=*P. braunii* var. *amphicephala* (Mayer) Hust.
20, 21
Pinnularia mesogongyla Ehrenb.
29, 98, 99, 119, 124
Pinnularia mesolepta (Ehrenb.) W. Sm.
20, 21, 27, 28, 29, 98, 99, 103, 116, 117, 124, 126
=*Navicula mesolepta* Ehrenb.
2, 97
=*P. interrupta* W. Sm.
29, 41, 111, 121
Pinnularia microstauron (Ehrenb.) Cleve
27, 28, 41, 110, 111, 112, 119, 121
Pinnularia molaris (Grun.) Cleve
100
Pinnularia neomajor Krammer
=*P. major* (Kütz.) Rabenh.
20, 21, 29, 87, 98, 99, 100, 110, 111, 112, 121, 124
=*Navicula major* (Kütz.) Ehrenb.
2, 3, 97
Pinnularia nobilis (Ehrenb.) Ehrenb.
29, 82, 87, 98, 99, 100, 117, 124
=*Navicula nobilis* Ehrenb.
3, 97
Pinnularia nodosa (Ehrenb.) W. Sm.
20, 21, 30, 32, 98, 103, 121, 124, 125, 126
Pinnularia obscura Krasske
30, 121
=*P. brebissonii* var. *diminuta* (Grun.) Cleve
20, 21
Pinnularia parvula (Ralfs) Cleve-Euler
29, 99, 124
Pinnularia polyonca (Bréb. ex Kütz.) W. Sm.
27, 28
Pinnularia rupestris Hantzsch
29, 77, 99, 124
Pinnularia ruttneri Hust.
98
Pinnularia socialis (Palmer) Hust.
100, 121
Pinnularia spitsbergensis Cleve
119
Pinnularia stauroptera (Grun.) Rabenh.
=*Navicula stauroptera* Grun.
2
Pinnularia stomatophora (Grun. ex A. Schmidt) Cleve
124
Pinnularia streptoraphe Cleve
119
Pinnularia subcapitata Greg.
29, 41, 99, 107, 124
Pinnularia subcapitata var. *hilseana* (Jan. ex Rabenh.) O. Müll.
=*P. hilseana* Jan. ex Rabenh.
121
Pinnularia subcapitata var. *paucistriata* (Grun.) Cleve
29, 98, 99, 124
Pinnularia sublinearis (Grun.) Cleve
119
Pinnularia substomatophora Hust.
1, 88
Pinnularia sudetica Hilse
29, 98, 99, 124
=*P. viridis* var. *sudetica* (Hilse) Hust.
41
Pinnularia termes Ehrenb.
=*Navicula termes* (Ehrenb.) O'Meara
2
Pinnularia torta (A. Mann) Patr.
98
Pinnularia undulata Greg.
20, 21, 116, 124, 125, 126
Pinnularia viridis (Nitzsch) Ehrenb.
41, 100, 103, 121
=*Navicula viridis* (Nitzsch) Ehrenb.
2, 3, 97
=*P. viridis* var. *commutata* (Grun. ex A. Schmidt) Cleve
121
Pinnularia spp.
1, 3, 20, 29, 39, 41, 82, 87, 92, 95, 99, 110, 112, 116, 117, 124, 126
Pinnunavis elegans (W. Sm.) Okuno
=*Navicula elegans* W. Sm.
124
Pleurosigma spp.
76, 124, 125

Sellaphora americana (Ehrenb.) Mann
=*Navicula americana* Ehrenb.
2
Sellaphora bacillum (Ehrenb.) Mann
=*Navicula bacillum* Ehrenb.
2, 105, 111
=*Navicula pseudobacillum* Grun.
2
Sellaphora laevissima (Kütz) Mann
=*Navicula laevissima* Kütz.
30, 31, 121
=*Navicula bacilliformis* Grun.
2, 3
Sellaphora pupula (Kütz.) Mereschkowsky
=*Navicula pupula* Kütz.
29, 88, 99, 103, 105, 111, 124
***Sellaphora pupula* f. *capitata* (Skvortzow & Meyer) Poulin, comb. nov.**
Basionyme: *Navicula pupula* var. *capitata* Skvortzow & Meyer 1928, p. 15, pl. 1, fig. 39
29, 99, 109, 111, 124, 126
***Sellaphora pupula* var. *elliptica* (Hust.) Poulin, comb. nov.**
Basionyme: *Navicula pupula* var. *elliptica* Hustedt 1911, p. 291, pl. 3, fig. 40
1, 27, 28, 98
***Sellaphora pupula* var. *mutata* (Krasske) Poulin, comb. nov.**
Basionyme: *Navicula mutata* Krasske 1929, p. 354, fig. 16
=*Navicula pupula* var. *mutata* (Krasske) Hust.
29, 98, 99, 121, 124, 126
Sellaphora pupula var. *rectangularis* (Greg.) Mereschkowsky
=*Navicula pupula* var. *rectangularis* (Greg.) Grun.
124
Stauroneis acuta W. Sm.
2, 3, 24, 25, 27, 28, 88, 100, 124
=*S. frickei* Heiden
87
Stauroneis anceps Ehrenb.
2, 29, 30, 97, 99, 111, 121, 124
=*S. anceps* var. *amphicephala* (Kütz.) V.H.
119
Stauroneis anceps f. *gracilis* Rabenh.
20, 21, 29, 41, 99, 111, 121, 124
Stauroneis anceps f. *linearis* Rabenh.
27, 28, 29, 98, 99, 124
Stauroneis biundulata Cleve-Euler
=*S. ignorata* Hust.
29, 98, 99, 124
Stauroneis fluminea Patr. & Freese
29, 99, 124
Stauroneis kriegeri Patr.
30, 121
Stauroneis legumen (Ehrenb.) Kütz.
124
Stauroneis nana Hust.
124, 125
Stauroneis nobilis Schumann
32
Stauroneis obtusa Lagerst.
119
Stauroneis perpusilla Grun. ex Cleve
=*S. perpusilla* var. *obtusiuscula* Grun.
119
Stauroneis phoenicenteron (Nitzsch) Ehrenb.
2, 20, 21, 24, 25, 29, 82, 87, 88, 97, 98, 99, 109, 110, 111, 112, 124
=*S. phoenicenteron* var. *amphilepta* (Ehrenb.) Cleve
119
Stauroneis phoenicenteron f. *gracilis* (Ehrenb.) Hust.
20, 21, 27, 28, 29, 98, 99, 124
Stauroneis phoenicenteron var. *brunii* (M. Perag. & Hérib.) Voigt
29, 99, 124
Stauroneis stodderi Greenleaf
20, 121
Stauroneis spp.
20, 22, 23, 29, 39, 87, 99, 116, 124, 125, 126

Rhopalodiales

Epithemia adnata (Kütz.) Rabenh.
=*E. zebra* (Ehrenb.) Kütz.
1, 27, 28, 30, 33, 88, 98, 121, 124
Epithemia adnata var. *porcellus* (Kütz.) Ross
=*E. zebra* var. *porcellus* (Kütz.) Grun.
30, 121
Epithemia adnata var. *proboscidea* (Kütz.) Hendey
=*E. zebra* var. *proboscidea* (Kütz.) Grun.
103
Epithemia adnata var. *saxonica* (Kütz.) Patr.
=*E. zebra* var. *saxonica* (Kütz.) Grun.
41
Epithemia argus (Ehrenb.) Kütz.
24, 25, 88, 97
Epithemia argus var. *longicornis* (Ehrenb.) Grun.
24 (*E. turgida* var. *longicornis*), 25 (*E. turgida* var. *longicornis*), 88 (*E. turgida* var. *longicornis*)
Epithemia hyndmanii W. Sm.
2 (*Rhopalodia hyndmanii*)
Epithemia sorex Kütz.
1, 24, 25, 30, 88, 98, 105, 111, 121, 124, 125
Epithemia turgida (Ehrenb.) Kütz.
2 (*Rhopalodia turgida*), 3, 24, 25, 88, 97, 105, 121, 124
Epithemia spp.
39, 124, 125, 126
Rhopalodia gibba (Ehrenb.) O. Müll.
2, 27, 28, 29, 97, 98, 99, 103, 111, 121, 124
=*Epithemia gibba* (Ehrenb.) Kütz.
3
=*Pinnularia gibba* (Ehrenb.) Ehrenb.
27, 28, 41, 100, 121

Rhopalodia gibba var. *ventricosa* (Kütz.) H. & M. Perag.
=*R. ventricosa* (Kütz.) O. Müll.
92
Rhopalodia gibberula (Ehrenb.) O. Müll.
27, 28, 30, 121
Rhopalodia operculata (C. Ag.) Håkansson
=*Epithemia musculus* Kütz.
3
=*R. musculus* (Kütz.) O. Müll.
2
Rhopalodia parallela (Grun.) O. Müll.
103
Rhopalodia rhopala (Ehrenb.) Hust.
105
Rhopalodia spp.
1, 88, 92

Thalassiophysales

Amphora commutata Grun.
124, 125
Amphora copulata (Kütz.) Schoeman & Archibald
=*A. affinis* Kütz.
2
=*A. ovalis* var. *affinis* (Kütz.) V.H.
3, 121
Amphora ovalis (Kütz.) Kütz.
1, 2, 3, 30, 88, 90, 92, 97, 98, 99, 100, 105, 111, 117, 121, 124
Amphora pediculus (Kütz.) Grun. ex A. Schmidt
=*A. ovalis* var. *pediculus* (Kütz.) V.H.
24, 25, 103, 121
Amphora perpusilla (Grun.) Grun.
30, 121
Amphora spp.
1, 39, 95, 116, 124, 125, 126

Surirellales

Campylodiscus echeneis Ehrenb. ex Kütz.
1, 24, 25, 88, 97
Campylodiscus noricus var. *hibernicus* (Ehrenb.) Grun.
1, 88, 98
=*C. hibernicus* Ehrenb.
24, 25
Campylodiscus spp.
3, 39, 124
Cymatopleura elliptica (Bréb. ex Kütz.) W. Sm.
2, 3, 24, 25, 30, 88, 97, 98, 121, 124
Cymatopleura elliptica var. *hibernica* (W. Sm.) V.H.
1, 24, 25, 88
=*C. elliptica* var. *nobilis* (Hantzsch) Hust.
121
Cymatopleura elliptica var. *ovata* Grun.
3 (var. *ovalis*), 121
Cymatopleura solea (Bréb.) W. Sm.
1, 2, 24, 25, 29, 30, 31, 88, 97, 98, 99, 121, 124
Cymatopleura solea var. *apiculata* (W. Sm.) Ralfs
3 (var. *spiculata*), 121
Entomoneis ornata (Bail.) Reimer
=*Amphiprora ornata* Bail.
1, 2, 88, 97, 98, 121
Entomoneis spp.
=*Amphiprora* spp.
39, 124, 126
Stenopterobia anceps (Lewis) Bréb. ex V.H.
=*Surirella anceps* Lewis
100
Stenopterobia curvula (W. Sm.) Krammer
=*S. intermedia* (Lewis) Bréb. ex V.H.
21, 29, 98, 99, 111, 116, 124, 125, 126
Stenopterobia pelagica Hust.
121
Stenopterobia sigmatella (Greg.) Ross
20
=*Nitzschia sigmatella* Greg.
100
Stenopterobia sp.
124
Surirella amphioxys W. Sm.
=*S. moelleriana* Grun. ex Möll.
30, 121
Surirella angusta Kütz.
1, 24 (*S. angustata*), 25 (*S. angustata*), 29 (*S. angustata*), 30, 88 (*S. angustata*), 99 (*S. angustata*), 103 (*S. angustata*), 111 (*S. angustata*), 116 (*S. angustata*), 121 (*S. angustata*), 124 (*S. angustata*), 125 (*S. angustata*), 126 (*S. angustata*)
=*S. apiculata* W. Sm.
2
Surirella asperrima Hust.
121
Surirella birostrata Hust.
121
Surirella biseriata Bréb.
1, 2, 3, 20, 21, 24, 25, 30, 88, 97, 111, 121, 124
Surirella biseriata var. *bifrons* (Ehrenb.) Hust.
121
Surirella biseriata var. *celebesiana* Hust.
24, 25, 88
Surirella biseriata var. *constricta* Hust.
1, 20, 21, 88
Surirella biseriata var. *diminuta* Cleve-Euler
24, 25, 88
Surirella capronii Bréb. ex Kitton
1, 88, 124
Surirella celebesiana Hust.
24, 25, 88
Surirella didyma Kütz.
29, 99, 124
Surirella elegans Ehrenb.
1, 2, 3, 24, 25, 29, 82, 88, 98, 99, 103, 105, 111, 117, 121, 124
=*S. elegans* var. *norvegica* (Eulenstein) Brun
30
=*S. saxonica* Auersw. ex Rabenh.
2

Surirella elegantula Hust.
124
Surirella elegantula f. *cuneata* Hust.
29, 99, 124
Surirella engleri f. *angustior* O. Müll.
24, 25, 88
Surirella fastuosa var. *recedens* (A. Schmidt) Cleve
=*S. recedens* A. Schmidt
2, 3
Surirella gracilis Grun.
2
Surirella guatimalensis Ehrenb.
1, 24, 25, 88, 98, 124
=*S. cardinalis* Kitton
2
Surirella lanicostata Østr.
98
Surirella lapponica A. Cleve
103
Surirella linearis W. Sm.
1, 2, 20, 27, 28, 29, 88, 99, 110, 111, 112, 121, 124
Surirella linearis var. *constricta* Grun.
121, 124
Surirella linearis var. *helvetica* (Brun) Meister
29, 99, 121, 124
Surirella minuta Bréb.
=*S. ovata* var. *salina* (W. Sm.) Rabenh.
121
Surirella oblonga Ehrenb.
82
Surirella ovalis Bréb.
30, 82, 87, 121
?*Surirella ovata*(25) Kütz.
1, 29, 30, 88, 98, 99, 111, 121, 124
=*S. ovalis* var. *ovata* (Kütz.) V.H.
97
Surirella papillifera Hust.
29, 99, 124
Surirella robusta Ehrenb.
1, 2, 3, 20, 21, 24, 25, 29, 30, 82, 87, 88, 98, 99, 100, 111, 117, 121, 124
Surirella robusta f. *lata* Hust.
121
Surirella robusta var. *splendida* (Ehrenb.) V.H.
29, 97, 99, 103, 121, 124
=*S. splendida* (Ehrenb.) Kütz.
2, 3
Surirella spiralis Kütz.
97, 124
Surirella striatula Turp.
2, 124
Surirella striolata Hust.
121
Surirella tenera Greg.
111, 121
Surirella tenuissima Hust.
121
Surirella verrucosa Pant.
124
Surirella spp.
2, 3, 20, 22, 23, 29, 39, 41, 76, 87, 95, 99, 116, 124, 125, 126

Chrysophyta(26)
Chromulinales

Bicosoeca(27) *conica* Lemm.
76
Bicosoeca cylindrica (Lackey) Bourrelly
27, 28, 76, 77, 124, 126
=*Domatomonas cylindrica* Lackey
124, 126
Bicosoeca lacustris var. *longipes* Zach.
5
Bicosoeca mitra var. *suecica* Skuja
76, 77 (var. *suecia*)
Bicosoeca multiannulata Skuja
76, 77
Bicosoeca ovata Lemm.
27, 28, 77
Bicosoeca petiolata (Stein) Bourrelly
76, 77
Bicosoeca spp.
20, 23, 121, 124
Calycomonas sp.
124
Chromulina asymmetrica (Doflein) Bourrelly
=*Pseudochromulina asymmetrica* Doflein
27, 28
Chromulina dubia Doflein
27, 28, 76
Chromulina erkensis Skuja
76, 121
Chromulina mikroplankton (Pascher) Pascher
27, 28, 76
Chromulina minor Pascher
76
Chromulina sphaerica Doflein
27, 28
Chromulina spp.
21, 22, 27, 28, 39, 42, 76, 77, 118, 121, 124
Chrysocapsa spp.
118
Chrysococcus biporus Skuja
77
Chrysococcus punctiformis Pascher
27, 28
Chrysococcus rufescens Klebs
27, 28, 76
Chrysococcus spp.
76, 118
=*Chrysococcocystis* spp.
27, 28
Chrysosphaera parvula (Pascher) Bourrelly
27, 28
Chrysosphaera sp.
124

Domatomonas sp.
124
Hydrurus foetidus (Villars) Trevisan
14, 37
Kephyrion boreale Skuja
118 (*Monosiga boreale*)
Kephyrion cupuliforme Conrad
76
Kephyrion hemisphaericum (Lackey) Conrad
76
Kephyrion obliquum Hilliard
27, 28, 76, 77, 118 (*Pseudokephyrion obliquum*), 124
Kephyrion petasatum Conrad
77
Kephyrion sitta Pascher
76, 77, 118
Kephyrion spirale (Lackey) Conrad
27, 28
Kephyrion spp.
39, 76, 106, 124
Kybotion spp.
20
Lepochromulina bursa Scherffel
5
Phaeaster aphanaster (Skuja) Bourrelly
=*Monochrysis aphanaster* Skuja
76
Phaeaster sp.
121

Monosigales
Aulomonas purdyi Lackey
27, 28, 77, 121, 124, 126
Codosiga spp.
=*Codonosiga* spp.
121, 124, 126
Desmarella moniliformis Kent
=*Desmarella phallanx* (Stein) Kent
124, 126
Desmarella spp.
23, 106, 124
Diploeca sp.
124
Monosiga baltica Willén
27, 28
Monosiga brevicolis Ruinen
76, 77, 124, 126
Monosiga ovata Kent
27, 28
Monosiga spp.
20, 76, 121, 124
Salpingoeca amphoridium Clark
20
Salpingoeca frequentissima (Zach.) Lemm.
20, 21, 121
Salpingoeca spp.
27, 28, 121
Sphaeroeca spp.
124 (*Sphaerocoeca*), 126
Stelexomonas dichotomus Lackey
27, 28, 121, 124, 126

Ochromonadales
Anthophysa vegetans (O.F. Müll.) Stein
21, 114
Catenochrysis hispida (Phillips) Perman
21, 114
***Catenochrysis synuroidea* (Prowse) Poulin, comb. nov.**
Basionyme: *Chrysodidymus synuroideus* Prowse 1962, p. 128, pl. 4, fig. n
21, 114
Catenochrysis spp.
124, 126
Chrysolykos planctonicus Mack
27, 28, 76, 77, 118, 124, 126
Chrysolykos skujae (Nauwerck) Bourrelly
76, 77, 106
=*Bitrichia skujae* (Nauwerck) Skuja
27, 28, 124
=*C. gracilis* Lund.
76, 77, 118
Chrysolykos spp.
76, 121
Chrysosphaerella brevispina Kors.
=*C. rodhei* Skuja
39
Chrysosphaerella conradii Bourrelly
114, 124
Chrysosphaerella longispina Lauterb.
5, 20, 21, 22, 23, 29, 31, 39, 76 (aussi sous *Chrysolykos longispina*), 87, 98, 99, 106, 109, 110, 111, 112, 117, 124, 125, 126
Chrysosphaerella multispina Bradley
21, 114
Chrysosphaerella sp.
20
Codonobotrys sp.
124
Cyclonexis sp.
124
Dendromonas spp.
124, 125
Dinobryon acuminatum Ruttner
76, 77, 116, 124
Dinobryon bavaricum Imhof
1, 5, 20, 21, 22, 23, 24, 25, 27, 28, 29, 31, 32, 39, 76, 77, 78, 88, 98, 99, 104, 106, 109, 110, 111, 112, 114, 116, 117, 118, 121, 124, 125, 126
=*D. stipitatum* Stein
124
Dinobryon bavaricum var. *medium* (Lemm.) Krieger
76
Dinobryon bavaricum var. *vanhoeffenii* (Bachmann) Krieger
29, 99, 110, 112, 114, 116, 124, 125
Dinobryon borgei Lemm.
27, 28, 76, 77, 124, 126

Dinobryon calyciforme Bachmann
100
Dinobryon campanulostipitum Ahlstrom
27, 28, 76, 77, 118
Dinobryon crenulatum W. & G.S. West
27, 28, 106, 124, 126
=*D. elegantissimum* f. *gallicum* Bourrelly
77
Dinobryon cylindricum Imhof
20, 21, 24, 25, 27, 28, 29, 76, 78, 88, 97, 98, 99, 110, 112, 116, 117, 124, 125, 126
Dinobryon cylindricum var. *alpinum* (Imhof) Bachmann
77, 124
Dinobryon cylindricum var. *palustre* Lemm.
5, 29, 99, 124
Dinobryon divergens Imhof
1, 5, 20, 21, 22, 24, 25, 27, 28, 29, 31 (sous *Navicula divergens*), 39, 76, 78, 82, 87, 88, 97, 98, 99, 104, 109, 110, 111, 112, 114, 116, 117, 124, 125, 126
Dinobryon divergens var. *angulatum* (Seligo) Brunnth.
1, 88
Dinobryon divergens var. *schauinslandii* (Lemm.) Brunnth.
29, 99, 124
Dinobryon korsikovii Matvienko
=*D. elegantissimum* (Kors.) Bourrelly
76, 77
Dinobryon lauzonicum Ahlstrom
20, 21, 124, 126
Dinobryon pediforme (Lemm.) Steinecke
5, 76
=*D. divergens* var. *pediforme* (Lemm.) Brunnth.
21
Dinobryon sertularia Ehrenb.
1, 5, 20, 21, 22, 23, 24, 25, 27, 28, 29, 31, 77, 78, 88, 92, 98, 99, 106, 109, 110, 111, 112, 114, 117, 118, 121, 124, 125, 126, 129
Dinobryon sertularia var. *protuberans* (Lemm.) Krieger
5, 20, 21, 98, 114
Dinobryon sociale Ehrenb.
1, 20, 21, 24, 25, 29, 31, 76, 88, 98, 99, 118, 121, 124, 126
Dinobryon sociale var. *americanum* (Brunnth.) Bachmann
1, 20, 29, 76, 77, 88, 97, 98, 99, 114, 124
=*D. americanum* Brunnth.
21
Dinobryon suecicum Lemm.
27, 28, 77 (*D. suecium*), 116, 124, 125, 126
Dinobryon suecicum var. *longispinum* Lemm.
5
Dinobryon vanhoeffenii (Krieger) Bachmann
20, 21, 23, 31, 76, 78, 98, 124, 126
Dinobryon spp.
20, 22, 23, 27, 28, 29, 39, 42, 99, 106, 117, 124, 125, 126

Epipyxis borgei (Lemm.) Hilliard & Asmund
=*Hyalobryon borgei* Lemm.
5
Epipyxis marchica (Lemm.) Hilliard & Asmund
20
Epipyxis mucicola (Pascher) Hilliard & Asmund
20, 21
Epipyxis ramosa (Lauterb.) Hilliard & Asmund
20, 21, 114
=*Hyalobryon ramosum* Lauterb.
5
Epipyxis tabellariae (Lemm.) G.M. Sm.
20, 21, 124, 126
=*Dinobryon tabellariae* (Lemm.) Pascher
27, 28, 29, 93, 98, 99, 124, 128
Epipyxis tubulosa (Mack) Hilliard & Asmund
124, 125, 126
Epipyxis utriculus Ehrenb.
20, 21, 124, 125, 126
=*Dinobryon utriculus* (Ehrenb.) Klebs
76
Epipyxis spp.
20, 22, 121, 124, 125, 126
=*Hyalobryon* spp.
23, 76, 77, 124, 125
Erkenia subaequicillata Skuja
76
Eusphaerella turfosa Skuja
21, 114
Eusphaerella sp.
39
Mallomonas acaroides Perty
5, 21, 34, 76 (*M. aceroides*), 114, 124
Mallomonas aculeata Bachmann
29, 99, 124
Mallomonas akrokomos Ruttner
124, 126
Mallomonas allorgei (Deflandre) Conrad
34
Mallomonas alpina Ruttner
27, 28, 76
Mallomonas apochromatica Conrad
1, 88, 121
Mallomonas calceolus Bradley
21, 114
Mallomonas caudata Iwanoff
20, 21, 121, 124, 126
Mallomonas crassisquama (Asmund) Fott
34
Mallomonas doignonii Bourrelly
5
Mallomonas elongata var. *americana* Bourrelly
5
Mallomonas fastigata Zach.
21
Mallomonas fastigata var. *kriegeri* Bourrelly
5, 114
Mallomonas hamata Asmund
21, 34, 114

Bitrichia longispina (Lund) Bourrelly
=*Diceras longispina* Lund
77, 118, 124
Bitrichia ochridana (Fott) Bourrelly
=*Diceras ochridana* Fott
116, 124, 126
Bitrichia phaseolus (Fott) Bourrelly
=*Diceras phaseolus* Fott
76, 77, 118
Bitrichia spp.
=*Diceras* spp.
76, 124, 125
Chrysamoeba mikrokonta Skuja
118
Chrysamoeba radians Klebs
76, 118 (*C. radiata*)
Chrysamoeba tetragena (Skuja) Matvienko
=*Rhizochrysis tetragena* Skuja
118
Chrysamoeba spp.
76, 118
Chrysidiastrum catenuatum Lauterb.
27, 28, 76, 77, 118 (*C. catenatum*)
Heliochrysis eradians Pascher
76 (*H. radians*), 77 (*H. radians*), 118 (*H. radians* et *H. radiata*)
Rhizochrysis limnetica G.M. Sm.
118
Stephanoporos sp.
121

Stylococcales

Chrysopyxis bipes Stein
20
Chrysopyxis iwanoffii Lauterb.
5
Chrysopyxis stenostoma Lauterb.
20
Chrysopyxis spp.
20, 21
Lagynion fulvum (Scherffel) Bourrelly
124
Lagynion macrotrachelum Pascher
20, 21
Lagynion triangulare var. *pyramidatum* Prescott
5
Lagynion spp.
20, 124
Stylococcus aureus Chodat
20

Xanthophyta

Xanthophyceae[28]

Mischococcales

Arachnochloris spp.
22, 23
Botrydiopsis arhiza Borzi
5
Botrydiopsis sp.
20
Botryochloris sp.
121
Bumilleriopsis spp.
124, 126
Characiopsis acuta (A. Br.) Borzi
20
Characiopsis cylindrica (Lamb.) Lemm.
23
Characiopsis longipes (Rabenh.) Borzi
20, 21, 124
Characiopsis subulata (A. Br.) Borzi
=*Characium subulatum* A. Br.
97
Characiopsis spp.
22, 93
Isthmochloron lobulatum (Näg.) Skuja
=*Tetraedron lobulatum* (Näg.) Hansg.
94
=?*Tetraedron lobulatum* var. *polyfurcatum* G.M. Sm.
97
Isthmochloron trispinatum (W. & G.S. West) Skuja
=*Arthrodesmus trispinatus* W. & G.S. West
20, 21, 27, 28, 76, 77 (*Staurodesmus trispinatus*)
Mischococcus confervicola Näg.
20
Ophiocytium capitatum Wolle
20, 21, 100
Ophiocytium capitatum var. *longispinum* (Möb.) Lemm.
20
Ophiocytium cochleare (Eichw.) A. Br.
20, 21, 92, 93, 97
Ophiocytium lagerheimii Lemm.
20, 21
Ophiocytium maius Näg.
97
Ophiocytium parvulum (Perty) A. Br.
5, 89, 92, 93, 100
Ophiocytium spp.
20, 23, 76, 124, 126
Perone sp.
20
Peroniella hyalothecae Gobi
20, 100
Peroniella planctonica G.M. Sm.
87, 97, 121
Pseudostaurastrum enorme (Ralfs) Chodat
=*Tetraedron enorme* (Ralfs) Hansg.
94
Pseudostaurastrum hastatum (Reinsch) Chodat
=?*Tetraedron hastatum* var. *palatinum* (Schmidle) Lemm.
24, 25, 88

Rhizochloridales
Rhizochloris sp.
121
Stipitococcus urceolatus W. & G.S. West
6
Stipitococcus spp.
20, 124, 125, 126

Tribonematales
Bumilleria sicula Borzi
20
Heterococcus sp.
20
Tribonema affine (G.S. West) G.S. West
93
Tribonema minimum Hazen
93
Tribonema minus (Klebs) Hazen
89, 92, 93, 97
Tribonema ulotrichoides Pascher
92
Tribonema utriculosum (Kütz.) Hazen
6, 93
Tribonema viride Pascher
93
=*T. bombycinum* Derb. & Sol.
6, 97, 100
Tribonema vulgare Pascher
93
Tribonema spp.
20, 22, 39, 93, 124, 126

Vaucheriales
Vaucheria debaryana Woronin
=*V. cruciata* (Vauch.) DC
79
Vaucheria dichotoma (L.) C. Ag.
79
Vaucheria geminata (Vauch.) DC
4, 6
Vaucheria geminata var. *racemosa* Walz
101
Vaucheria ornithocephala C. Ag.
incl. *V. ornithocephala* f. *genuina* Heering
96
Vaucheria schleicheri De Wildemann
16, 17
Vaucheria sessilis (Vauch.) DC
97, 101
Vaucheria spp.
20, 37, 92, 97, 101

Cryptophyta[(29)]
Cryptophyceae
Cryptomonadales
Chilomonas paramecium Ehrenb.
21, 114
Chilomonas sp.
124
Chroomonas nordstedtii Hansg.
121
Cryptaulax sp.
76
Cryptomonas brevis Schiller
27, 28
Cryptomonas caudata Schiller
76, 77, 118
Cryptomonas erosa Skuja
27, 28, 76, 77, 102, 118, 121
Cryptomonas erosa var. *reflexa* Marsson
27, 28, 77, 118, 121
Cryptomonas marssonii Skuja
21, 76, 77, 114, 118, 121
Cryptomonas obovata Skuja
27, 28, 76, 121
Cryptomonas ovata Ehrenb.
6, 21, 76, 77, 118, 121
Cryptomonas phaseolus Skuja
77, 121
Cryptomonas pyrenoidifera Geitler
77
Cryptomonas reflexa Skuja
121
Cryptomonas rostrata Troitkzaja
118
Cryptomonas rufescens Skuja
27, 28
Cryptomonas spp.
22, 39, 121, 124
Katablepharis ovalis Skuja
27, 28, 76, 77, 118
Katablepharis sp.
22
Rhodomonas lacustris Pascher & Ruttner
76
Rhodomonas lens Pascher & Ruttner
27, 28, 76
Rhodomonas minuta Skuja
27, 28, 76, 77, 118, 121
Rhodomonas minuta var. *nannoplanctica* Skuja
27, 28, 76, 77, 118
Rhodomonas spp.
22, 39
Sennia parvula Skuja
76

Cyanophyta[(30)]
Cyanophyceae
Chamaesiphonales
Chamaesiphon curvatus Nordst.
20, 121
Chamaesiphon incrustans Grun.
6, 93, 101, 107, 121
Chamaesiphon minimus Schmidle
94
Pascherinema gracile (Pascher) De Toni
5

Chroococcales

Aphanocapsa biformis A. Br.
5, 76, 77
Aphanocapsa delicatissima W. & G.S. West
5, 24, 25, 76, 88, 106, 118
Aphanocapsa elachista W. & G.S. West
5, 20, 24, 25, 29, 88, 92, 99, 106, 111, 124
Aphanocapsa elachista var. *conferta* W. & G.S. West
20, 27, 28, 97
Aphanocapsa elachista var. *planctonica* G.M. Sm.
27, 28, 92, 117, 124
Aphanocapsa grevillei (Hass.) Rabenh.
20, 21, 92, 96, 100, 129
Aphanocapsa pulchra (Kütz.) Rabenh.
21, 90, 92, 94, 129
Aphanocapsa richteriana Hieron.
100
Aphanocapsa spp.
20, 22, 23, 76, 99, 106, 117, 118, 124
Aphanothece castagnei (Bréb.) Rabenh.
92, 93, 129
Aphanothece microscopica Näg.
6, 40, 110, 112
Aphanothece nidulans Richter
5, 29, 76 (*Aphanocapsa nidulans*), 92, 97, 98, 99, 106, 124
Aphanothece saxicola Näg.
92, 129
Aphanothece stagnina (Spreng.) A. Br.
6, 20, 92, 129
Aphanothece spp.
6, 22, 23, 29, 39, 76, 99, 105, 116, 121, 124, 125
Bacularia sp.
20
Chroococcus dispersus (Keissler) Lemm.
27, 28, 29, 76, 92, 97, 99, 106, 124
Chroococcus dispersus var. *minor* G.M. Sm.
27, 28, 118
Chroococcus giganteus W. West
124, 126
Chroococcus gomontii Nyg.
29, 99, 124
Chroococcus limneticus Lemm.
5, 24, 25, 29, 88, 92, 93, 94, 97, 98, 99, 106, 110, 112, 121, 124
Chroococcus limneticus var. *elegans* G.M. Sm.
24, 25, 88
Chroococcus minimus (Keissler) Lemm.
27, 28, 29, 94, 99, 124
Chroococcus minor (Kütz.) Näg.
20, 77, 92, 121
Chroococcus minutus (Kütz.) Näg.
27, 28, 83, 84, 87, 92, 93, 94, 124
Chroococcus minutus var. *maximus* Nyg.
92
Chroococcus prescottii Drouet & Daily
20, 21, 124
Chroococcus turgidus (Kütz.) Näg.
5, 20, 21, 29, 76, 90, 92, 93, 94, 97, 99, 100, 101, 117, 121, 124, 125, 126, 129
Chroococcus turgidus var. *maximus* Nyg.
92, 93
Chroococcus varius A. Br.
124
Chroococcus westii (W. West) Boye-Petersen
124
Chroococcus spp.
20, 22, 23, 24, 29, 39, 76, 99, 106, 116, 117, 124, 125, 126
Coelosphaerium confertum W. & G. S. West
92, 93
Coelosphaerium dubium Grun.
116, 124, 125
Coelosphaerium kuetzingianum Näg.
1, 20, 21, 29, 39, 88, 90, 92, 94, 97, 99, 124
Coelosphaerium naegelianum Unger
1, 20, 21, 24, 25, 27, 28, 29, 88, 92, 93, 98, 99, 116, 124, 125, 126
=*Gomphosphaeria naegeliana* (Unger) Lemm.
5, 39, 111
Coelosphaerium naegelianum var. *lemmermanni* Elenkin & Hollerb.
93, 94
Coelosphaerium pallidum Lemm.
20
Coelosphaerium pusillum van Goor
29, 99, 124
Coelosphaerium spp.
20, 22, 106, 110, 112, 124, 126
Cyanarcus sp.
76, 77
?*Dactylococcopsis acicularis* Lemm.
104, 106, 116, 124, 125, 126
?*Dactylococcopsis fascicularis* Lemm.
124
?*Dactylococcopsis irregularis* G.M. Sm.
29, 99, 104, 116, 124, 126
Entophysalis spp.
36, 37
Eucapsis alpina Clem. & Shantz
5, 20, 21, 124
Eucapsis sp.
39
Gloeocapsa alpina Näg.
124
Gloeocapsa arenaria (Hass.) Rabenh.
37
Gloeocapsa atrata (Turp.) Kütz.
83, 84
Gloeocapsa decorticans (A. Br.) Richter
92
Gloeocapsa dermatochroa Näg.
89 (*G. dermachroa*), 93
Gloeocapsa kuetzingiana Näg.
129

Gloeocapsa limnetica Lemm.
29, 99, 109, 111, 124
Gloeocapsa minima (Keissler) Hollerb.
29, 99, 108, 109, 110, 111, 112, 124
Gloeocapsa minuta (Kütz.) Hollerb.
29, 99, 124
Gloeocapsa montana Kütz.
92
Gloeocapsa ralfsiana (Harv.) Kütz.
92
Gloeocapsa rupestris Kütz.
129
Gloeocapsa turgida (Kütz.) Hollerb.
110, 111, 112
Gloeocapsa spp.
20, 37, 121, 124
Gloeothece confluens Näg.
92
Gloeothece dubia (Wartm.) Geitler
27, 28
Gloeothece linearis Näg.
20, 29, 39, 84, 98, 99, 116, 124
Gloeothece rupestris (Lyngb.) Born.
84, 92
=*Anacystis rupestris* (Lyngb.) Drouet & Daily
100
Gloeothece rupestris var. *maxima* W. West
129
Gloeothece spp.
20, 22, 124
Gomphosphaeria aponica Kütz.
24, 25, 31, 39, 88, 89, 92, 93, 94, 97, 124
Gomphosphaeria aponica var. *cordiformis* Wille
92
Gomphosphaeria lacustris Chodat
1, 5, 20, 21, 27, 28, 29, 32, 39, 76, 88, 98, 99, 110, 112, 116, 117, 118, 121, 124, 125, 126
Gomphosphaeria pusilla (van Goor) Komárek
5
Gomphosphaeria spp.
22, 23, 39, 76, 95, 106, 121, 124
Lithococcus spp.
20, 105
Merismopedia chondroidea Wittr. & Nordst.
20, 21
Merismopedia convoluta Bréb.
116, 124
Merismopedia elegans A. Br.
1, 5, 20, 29, 88, 92, 94, 98, 99, 100, 105, 109, 116, 117, 124, 125, 126
Merismopedia glauca (Ehrenb.) Näg.
5, 6, 20, 21, 24, 25, 82, 88, 90, 92, 97, 98, 99, 101, 111, 116, 117, 121, 124, 125, 126, 129
Merismopedia major (G.M. Sm.) Geitler
29, 92, 98, 99, 124
Merismopedia minima Beck
106
Merismopedia punctata Meyen
1, 5, 20, 21, 27, 28, 29, 88, 90, 92, 98, 99, 109, 110, 111, 112, 117, 124, 126
Merismopedia tenuissima Lemm.
5, 6, 20, 21, 22, 23, 27, 28, 29, 76, 77, 92, 94, 97, 98, 99, 104, 106, 118, 121, 124, 125
Merismopedia trolleri Bachmann
20, 21
Merismopedia spp.
20, 22, 23, 29, 39, 99, 116, 117, 124, 125, 126
=*Agmenellum* sp.
95
=*Holopedium* spp.
22, 23
Microcystis aeruginosa (Kütz.) Kütz.
1, 20, 21, 24, 25, 29, 88, 94, 97, 98, 99, 111, 116, 117, 124, 126
=*M. ochracea* Lemm.
97
=*Polycystis aeruginosa* Kütz.
82, 87, 100
Microcystis elabens Kütz.
92, 129
Microcystis elabens var. *minor* Nyg.
92
Microcystis firma (Bréb. & Lenorm.) Schmidle
129
Microcystis flos-aquae (Wittr.) Kirchn.
116, 121, 124, 129
Microcystis marginata (Menegh.) Kütz.
88, 117, 121, 124
Microcystis minutissima W. West
29, 99, 124
Microcystis pulverea (Wood) Forti
92, 124 (*M. pulvurea*)
Microcystis pulverea var. *incerta* (Lemm.) Crow
92
=*M. incerta* Lemm.
20, 21, 92
=*Polycystis incerta* Lemm.
100
Microcystis robusta (Clark) Nyg.
116, 124
Microcystis spp.
20, 22, 23, 106, 110, 112, 116, 121, 124, 125, 126
=*Anacystis* sp.
20
=*Polycystis* spp.
22, 39
Myxobactron hirudiforme G.S. West
=*Dactylococcopsis hirudiformis* (G.S. West) Geitler
124, 125
?*Palmogloea protuberans* (Sm. & Sow.) Kütz.
=?*Aphanocapsa rivularis* (Carm.) Rabenh.
24, 25, 29, 88, 99, 124
=?*Gloeothece distans* Stizenb.
92
Rhabdoderma gorskii Wolosz.
29 (aussi sous *Synechococcus gorskii*), 76, 99, 117, 124 (aussi sous *Synechococcus gorskii*)

Rhabdoderma gorskii var. *spirale* Lundberg
29 (*Synechococcus gorskii* var. *spirale*), 99, 116, 124 (aussi sous *Synechococcus gorskii* var. *spiroides*)
Rhabdoderma irregulare (Naumann) Geitler
27, 28
Rhabdoderma lineare Schmidle & Lauterb.
5, 20, 21, 27, 28, 29, 39, 98, 99, 116, 117, 118, 124, 125
=*Synechococcus linearis* (Schmidle & Lauterb.) Komárek
29, 99, 124
Rhabdoderma minima Lemm.
29, 99, 124
Rhabdoderma sigmoidea Moore & Carter
124
Rhabdoderma spp.
20, 22, 23, 29, 76, 99, 116, 124, 126
Rhabdogloea clathrata (W. & G.S. West) Komárek
=*Aphanothece clathrata* W. & G.S. West
24, 25, 27, 28, 29, 76, 88, 92, 94, 99, 106, 109, 110, 111, 112, 124
=*Aphanothece clathrata* var. *brevis* Bachmann
76
Rhabdogloea ellipsoidea Schröder
=*Aphanothece ellipsoidea* (Schröder) Bourrelly
124
=*Dactylococcopsis smithii* R. & F. Chodat
29, 98, 99, 106, 109, 110, 111, 112, 124, 125, 126
Rhabdogloea linearis (Geitler) Komárek
=*Dactylococcopsis linearis* Geitler
29, 99, 124
Rhabdogloea spp.
=*Dactylococcopsis* spp.
22, 23, 76, 116, 124, 125, 126
Synechococcus elongatus Näg.
109, 110, 112, 121
Synechococcus major Schröter
93
Synechococcus major var. *maximus* Lemm.
92
Synechococcus salina Frémy
99, 124
Synechococcus spp.
29, 116, 124
Synechocystis aquatilis Sauv.
20
Synechocystis salina Wislouch
29, 124
Synechocystis spp.
110, 112, 124

Nostocales

Anabaena affinis Lemm.
1, 29, 88, 99, 105, 124
=*A. catenula* var. *affinis* (Lemm.) Geitler
124
Anabaena aphanizomenoides Forti
1, 88, 98
Anabaena augstumalis Schmidle
92
Anabaena catenula (Kütz.) Born. & Flah.
92
Anabaena catenula var. *solitaria* (Klebahn) Geitler
=*A. solitaria* Klebahn
124
Anabaena circinalis Rabenh. ex Born. & Flah.
32, 97, 124
Anabaena constricta (Szafer) Geitler
20, 121
Anabaena cylindrica Lemm.
93
Anabaena flos-aquae (Lyngb.) Bréb. ex Born. & Flah.
20, 21, 22, 24, 25, 27, 28, 29, 39, 82, 88, 89, 92, 93, 98, 99, 104, 106, 110, 112, 116, 117, 124, 125, 126
=*A. lemmermannii* Richter
20, 21, 24, 25, 88
Anabaena inaequalis (Kütz.) Born. & Flah.
6, 92, 93, 94, 97, 101
Anabaena levanderi Lemm.
1, 88
Anabaena oscillarioides Bory ex Born. & Flah.
6, 91, 92, 101
Anabaena planctonica Brunnth.
24, 25, 27, 28, 88
Anabaena sphaerica Born. & Flah.
124
Anabaena spiralis Thompson
99, 117
Anabaena spiroides Klebahn
24, 25, 88, 98, 105, 116, 121, 124, 125, 126
Anabaena spiroides f. *crassa* (Lemm.) Elenkin
1, 29 (var. *crassa*), 99, 124
Anabaena subcylindrica Borge
29, 99, 124
Anabaena torulosa (Carm.) Lagerh.
97 (*A. tortulosa*)
Anabaena variabilis Kütz. ex Born. & Flah.
29, 86, 93, 99, 124
Anabaena spp.
20, 22, 23, 29, 78, 87, 92, 93, 94, 95, 99, 100, 106, 111, 116, 118, 121, 124, 125, 126
Aphanizomenon flos-aquae (L.) Ralfs ex Born. & Flah.
22, 24, 25, 29, 78, 88, 98, 99, 111, 124
Aphanizomenon spp.
22, 39
Aulosira aenigmatica Frémy
20
Aulosira implexa Born. & Flah.
20, 21, 86
Aulosira sp.
20
Calothrix adscendens (Näg.) Born. & Flah.
96, 100

Calothrix atricha Frémy
20

Calothrix braunii Born. & Flah.
89, 92, 93, 94, 121

Calothrix confervicola (Dillw.) C. Ag. ex Born. & Flah.
101

Calothrix epiphytica W. & G.S. West
20, 21

Calothrix fusca (Kütz.) Born. & Flah.
5, 100, 129

Calothrix parietina (Näg.) Thur. ex Born. & Flah.
6, 40, 42, 94, 100, 129

Calothrix spp.
6, 20, 121

Cylindrospermum licheniforme (Bory) Kütz. ex Born. & Flah.
124

Cylindrospermum majus Kütz. ex Born. & Flah.
6

Cylindrospermum minimum G.S. West
121

Cylindrospermum stagnale (Kütz.) Born & Flah.
92 (*C. stagnatile*)

Cylindrospermum spp.
20, 100

Dichothrix gypsophila (Kütz.) Born. & Flah.
84, 92, 94, 100

Dichothrix hosfordii (Wolle) Born.
86, 100

Dichothrix orsiniana (Kütz.) Born & Flah.
84, 89, 96, 100, 128

Dichothrix sp.
36

Gloeotrichia echinulata (J.E. Sm. & Sow.) Richter
97, 124

Gloeotrichia intermedia (Lemm.) Geitler
20

Gloeotrichia natans Rabenh. ex Born. & Flah.
100, 121
=*Rivularia natans* Hedwig ex Fries
97

Gloeotrichia pisum (Ag.) Thur. ex Born. & Flah.
20, 100
=*Rivularia pisum* Ag.
96

Gloeotrichia sp.
20

Homoeothrix juliana (Menegh.) Kirchn.
=*Calothrix juliana* (Menegh.) Born. & Flah.
92

Isocystis infusionum Borzi
121

Microchaete diplosiphon Gom.
=*Fremyella diplosiphon* (Gom.) Drouet
85

Microchaete tenera Thur. ex Born. & Flah.
5

Nodularia harveyana (Thwaites) Thur. ex Born. & Flah.
89, 93, 121

Nodularia spumigena Mert. ex Born. & Flah.
20, 21, 89, 93

Nodularia spumigena var. *litorea* (Kütz.) Born. & Flah.
20, 21

Nodularia sp.
124

Nostoc coeruleum Lyngb. ex Born. & Flah.
92, 93, 94

Nostoc commune Vauch. ex Born. & Flah.
20, 94, 129

Nostoc microscopicum Carm. ex Born. & Flah.
92, 100

Nostoc linckia (Roth) Born. ex Born. & Flah.
92, 96

Nostoc paludosum Kütz. ex Born. & Flah.
92, 93, 124

Nostoc piscinale Kütz. ex Born. & Flah.
92

Nostoc pruniforme (L.) Ag. ex Born. & Flah.
20, 84, 97

Nostoc sphaericum Vauch. ex Born. & Flah.
92, 94

Nostoc verrucosum Vauch. ex Born. & Flah.
122

Nostoc spp.
20, 36, 92, 93, 94, 101, 121, 124

Petalonema alatum (Borzi ex Born. & Flah.) Geitler
92

Raphidiopsis sp.
20

Rivularia biasolettiana Menegh. ex Born. & Flah.
94

Rivularia haematites (Lam. & DC) Ag. ex Born. & Flah.
101

Rivularia spp.
20, 92, 105, 121

Scytonema arcangelii Born. & Flah.
92

Scytonema arcangelii f. *minus* Frémy
92 (f. *minor*)

Scytonema coactile Mont. ex Born. & Flah.
87

Scytonema cincinnatum Thur. ex Born. & Flah.
122
=*S. crispum* (Ag.) Born.
96, 97

Scytonema flavo-viride (Kütz.) Born. & Flah.
100

Scytonema figuratum Ag. ex Born. & Flah.
=*S. mirabile* (Dillw.) Dillw. ex Fries
20

Scytonema myochrous (Dillw.) Ag. ex Born. & Flah.
84, 92

Scytonema ocellatum (Dillw.) Lyngb. ex Born. & Flah.
97, 129
Scytonema tolypothrichoides Kütz. ex Born. & Flah.
100
Scytonema spp.
20, 29, 37, 92, 99, 121, 124
Tolypothrix byssoidea (Hass. ex Born. & Flah.) Kirchn.
=*T. truncicola* (Rabenh.) Thur.
101
Tolypothrix distorta (O.F. Müll.) Kütz. ex Born. & Flah.
40, 89, 93, 94, 129
Tolypothrix distorta var. *penicillata* (Ag.) Lemm.
129
Tolypothrix limbata Thur. ex Born. & Flah.
100, 129
Tolypothrix setchellii Coll.
29, 99, 124
Tolypothrix tenuis Kütz. ex Born. & Flah.
92, 94, 96, 97, 100, 129
=*T. lanata* Wartm., non Kütz.
40, 92, 100
Tolypothrix spp.
20, 92, 121, 124

Oscillatoriales

Lyngbya aerugineo-coerulea (Kütz.) Gom.
121
Lyngbya aestuarii (Mert.) Liebm. ex Gom.
101, 121
Lyngbya bipunctata Lemm.
29, 99, 124
Lyngbya birgei G.M. Sm.
121
Lyngbya diguetii Gom.
121
Lyngbya lagerheimii (Möb.) Gom.
92
Lyngbya latissima Prescott
121
Lyngbya limnetica Lemm.
29, 92, 99, 106, 124
Lyngbya major Menegh. ex Gom.
20, 21 (*L. maior*), 121
Lyngbya majuscula Harv. ex Gom.
1, 6, 88, 105
Lyngbya martensiana Menegh. ex Gom.
92, 93
Lyngbya nordgardii Wille
121
Lyngbya pseudospirulina Geitler
39
Lyngbya purpurea (Hook. & Harv.) Gom.
121
Lyngbya pusilla (Rabenh.) Hansg.
94
Lyngbya subtilis W. West
129
Lyngbya taylorii Drouet & Strickland
121
Lyngbya vacuolifera Skuja
77
Lyngbya versicolor (Wartm.) Gom.
121
Lyngbya spp.
1, 6, 20, 22, 23, 39, 96, 111, 121, 124
Microcoleus chthonoplastes (Mert.) Zanard. ex Gom.
97
Microcoleus lacustris (Rabenh.) Farl.
96
Microcoleus paludosus (Kütz.) Gom.
92
Microcoleus steenstrupii Petersen
20
Microcoleus vaginatus (Vauch.) Gom.
92, 100
Microcoleus spp.
36, 121
Oscillatoria acutissima Kuff.
29, 99, 121, 124
Oscillatoria agardhii Gom.
6, 20, 97, 121
Oscillatoria amoena (Kütz.) Gom.
92, 121
Oscillatoria amphibia Ag. ex Gom.
97, 121
Oscillatoria amphigranulata van Goor
76
Oscillatoria animalis Ag. ex Gom.
92, 94
Oscillatoria breviarticulata Frémy
98
Oscillatoria brevis Kütz. ex Gom.
88, 89, 92, 93
Oscillatoria chalybea Mert. ex Gom.
92
Oscillatoria formosa Bory ex Gom.
97
Oscillatoria granulata Gardner
88, 121
Oscillatoria grunowiana var. *articulata* (Gardner) Drouet
=*O. articulata* Gardner
121
Oscillatoria guttulata van Goor
1, 88
Oscillatoria hamelii Frémy
20, 121
Oscillatoria inaequalis Cholnoky
121
Oscillatoria irrigua Kütz. ex Gom.
29, 99, 124
Oscillatoria lacustris (Klebahn) Geitler
121
Oscillatoria leptotricha var. *splendida* (Grev.) Cooke
101

Oscillatoria limosa (Dillw.) Ag. ex Gom.
1, 20, 24, 25, 88, 92, 93, 94, 111, 121, 129
Oscillatoria limnetica Lemm.
76, 77, 106, 110, 112, 121
Oscillatoria minima Gicklhorn
118
Oscillatoria nigra Vauch. ex Gom.
121
Oscillatoria okeni Ag. ex Gom.
94
Oscillatoria ornata Kütz. ex Gom.
121
Oscillatoria princeps Vauch. ex Gom.
92, 93, 94, 111, 121
Oscillatoria prolifica (Grev.) Gom.
1, 88, 90, 92, 105, 121 (*O. prolifera*)
Oscillatoria rubescens DC ex Gom.
121
Oscillatoria sancta Kütz. ex Gom.
92, 93, 97, 121
Oscillatoria splendida Grev. ex Gom.
92, 93, 94, 100, 121
Oscillatoria subbrevis Schmidle
1, 88, 121
Oscillatoria tenuis Ag. ex Gom.
1, 24, 25, 40, 88, 90, 92, 93, 94, 96, 100, 101, 121
Oscillatoria terebriformis Ag. ex Gom.
121
Oscillatoria spp.
1, 6, 20, 22, 23, 27, 28, 29, 39, 95, 99, 111, 121, 124, 125
Phormidium ambiguum Gom.
121
Phormidium autumnale (Ag.) Trevisan
4, 20
Phormidium corium (Ag.) Kütz. ex Gom.
100, 121
Phormidium inundatum Kütz. ex Gom.
20, 100
Phormidium laminosum (Ag.) Gom.
100
Phormidium molle (Kütz.) Gom.
100
Phormidium mucicola Naumann & Hub.-Pest.
20, 24, 25, 27, 28, 29, 88, 99, 124
Phormidium retzii (Ag.) Kütz. ex Gom.
100, 121
Phormidium tenue (Menegh.) Gom.
27, 28, 97
Phormidium uncinatum (Ag.) Gom.
100
Phormidium spp.
20, 36, 37
Plectonema notatum Schmidle
5
Plectonema roseolum (Richter) Gom.
85, 100
Pseudanabaena catenata Lauterb.
110, 111, 112, 121
Pseudanabaena schmidlei Jaag
109, 110, 112
Pseudanabaena sp.
121
Schizothrix fuscescens Kütz. ex Gom.
129
Schizothrix lardacea (Rabenh.) Gom.
129
Schizothrix rivularis (Wolle) Drouet
121
Schizothrix sp.
37
Spirulina jenneri Kütz. ex Gom.
105
Spirulina laxa G.M. Sm.
121
Spirulina laxissima G.S. West
20, 21, 27, 28
Spirulina major Kütz. ex Gom.
6
Spirulina nordstedtii Gom.
20, 121 (*S. nordestii*)
Spirulina princeps W. & G.S. West
20, 94, 97
Spirulina spp.
20, 22, 23, 39, 95, 124

Pleurocapsales

Chroococcopsis gelatinosum (Geitler) Bourrelly
121 (*Chroscoocopsis gelatinosum*)
Dermocarpa kerneri (Hansg.) Bourrelly
=*Xenococcus kerneri* Hansg.
121 (*X. keineri*)
Dermocarpa sp.
121
Hydrococcus cesatii (Rabenh.) Rabenh.
=*Oncobyrsa cesatiana* Rabenh.
129
Hydrococcus sp.
121 (*Hydroccus* sp.)
Myxosarcina burmensis Skuja
5
Pleurocapsa spp.
121

Stigonematales

Albrightia spp.
20
Fischerella muscicola (Borzi ex Born. & Flah.) Gom.
20
Hapalosiphon hibernicus W. & G.S. West
5, 94
Hapalosiphon intricatus W. & G.S. West
5, 20
Hapalosiphon pumilus Kirchn. ex Born. & Flah.
100
Hapalosiphon spp.
20, 36, 37
Loefgrenia sp.
121

Nostochopsis lobatus Wood ex Born. & Flah.
86, 121
Nostochopsis spp.
20
Stigonema hormoides (Kütz.) Born. & Flah.
5, 100
Stigonema informe Kütz. ex Born. & Flah.
92, 129
Stigonema mamillosum (Lyngb.) Ag. ex Born. & Flah.
5, 6, 20, 100
Stigonema minutum (Ag.) Hass. ex Born. & Flah.
96, 100
Stigonema ocellatum (Dillw.) Thur. ex Born. & Flah.
6, 36, 37, 92, 100
Stigonema spp
20, 37, 92, 121, 124

Euglenophyta[31]
Euglenophyceae
Euglenales

Anisonema acinus Duj.
21, 114
Anisonema dimorphum Skuja
21, 114
Anisonema sp.
114
Astasia acus (Kors.) Pringsh.
=*Cyclidiopsis acus* Kors.
21, 114,
Astasia comma Pringsh.
21, 114
Astasia harrisii Pringsh.
114
Astasia skadowskii Kors.
21
Calycimonas physaloides Christen
21, 114
Colacium arbuscula Stein
20, 21
Colacium vesiculosum Ehrenb.
20, 21
Colacium sp.
124
Distigma proteus Ehrenb.
21, 114
Distigma sennii Pringsh.
21, 114
Entosiphon sulcatum (Duj.) Stein
21, 114
Euglena acus Ehrenb.
21, 109, 110, 111, 112, 114
Euglena acus var. *hyalina* Klebs
21, 114
Euglena acus var. *longissima* Defl.
21, 114
Euglena acus var. *rigida* Hübner
20, 21
Euglena adhaerens Matvienko
21 (*E. adhereus*), 114
Euglena agilis Carter
=*E. pisciformis* Klebs
21, 110, 112, 114
Euglena chadefaudii Bourrelly
21, 114
Euglena deses Ehrenb.
97
Euglena elastica Prescott
20, 21
Euglena fundoversata Johnson
21
Euglena gracilis Klebs
121
Euglena oblonga Schmitz
21
Euglena oxyuris Schmarda
21
Euglena sanguinea Ehrenb.
20, 21, 114
Euglena spirogyra Ehrenb.
20, 21, 97, 114
Euglena spirogyra var. *fusca* Kelbs
=*E. fusca* (Klebs) Lemm.
21, 114
Euglena splendens Dang.
21, 114
Euglena tatrica Czosn.
21, 114
Euglena viridis Ehrenb.
97
Euglena spp.
1, 6, 20, 22, 23, 29, 88, 92, 93, 98, 99, 109, 111, 121, 124
Gyropaigne kosmos Skuja
21, 114
Gyropaigne lefevrei Bourrelly & Georges
21
?*Heteronema klebsii* Senn
21, 114
?*Heteronema nebulosum* (Duj.) Klebs
21, 114
Lepocinclis fusiformis (Carter) Lemm.
20, 21, 121
Lepocinclis ovum (Ehrenb.) Lemm.
21, 110, 112, 114, 121
Lepocinclis sphagnophila Lemm.
20, 21, 121
Lepocinclis spp.
20, 124
Menoidium falcatum Zach.
21, 114
Menoidium pellucidum Perty
21, 114
?*Peranema cuneatum* Playfair
21, 114
Petalomonas africana Bourrelly
5

Petalomonas quadrilineata Pénard
21
Petalomonas sphagnophila Christen
114
Petalomonas steinii Klebs
21, 114
Petalomonas sp.
124
Phacus acuminatus Stokes
21, 94, 114, 121
Phacus asymmetrica Prescott
121 (*P. asymetrica*)
Phacus caudatus Hübner
97, 121
Phacus curvicauda Swir.
121
Phacus gigas Da Cunha
21, 114
Phacus helikoïdes Pochm.
20, 21, 114
Phacus inflexus (Kiss) Pochm.
21, 114
Phacus lefevrei Bourrelly
21, 114
Phacus longicauda (Ehrenb.) Duj.
5, 20, 21, 114
Phacus orbicularis Hübner
21
Phacus pleuronectes (O.F. Müll.) Duj.
6, 20, 21, 92, 97, 114
Phacus pyrum (Ehrenb.) Stein
111
Phacus spiralis Allerge & Jahn
21, 114
Phacus splendens Pochm.
21
Phacus suecicus Lemm.
20 (*P. suecica*), 21, 114
Phacus tortus (Lemm.) Skvortzow
5, 21, 114
Phacus tropidonotus Conrad
21, 114
Phacus spp.
1, 20, 23, 88, 111, 121, 124
Pseudoperanema acus (Ehrenb.) Skvortzow ex Compère
=*Heteronema acus* (Ehrenb.) Stein
21, 114
Pseudoperanema trichophorum (Ehrenb.) Larsen
=*Peranema trichophorum* (Ehrenb.) Stein
21, 114
Rhabdomonas costata (Kors.) Pringsh.
21, 114
Trachelomonas allia var. *depauperata* Bourrelly
5
Trachelomonas armata (Ehrenb.) Stein
21
Trachelomonas armata f. *pseudolongispina* Defl.
114
Trachelomonas hispida (Perty) Stein
20, 21, 97
Trachelomonas hispida f. *punctata* Defl.
114
Trachelomonas kelloggii Skvortzow
20, 21 (*T. kellogii*), 114
Trachelomonas lemmermannii Wolosz.
21, 114
Trachelomonas lemmermannii var. *acuminata* Defl.
114
Trachelomonas megalacantha var. *crenulatocollis* Bourrelly
21, 114
Trachelomonas mirabilis Swir.
21, 114
Trachelomonas oblonga var. *truncata* Lemm.
97 (var. *punctata*)
Trachelomonas pulchella Drezepolski
20, 21
Trachelomonas raciborskii Wol.
21, 114
Trachelomonas rugulosa Stein
97
Trachelomonas superba Swir.
21, 114
Trachelomonas superba var. *duplex* Defl.
20
Trachelomonas varians f. *globosa* Defl.
6
Trachelomonas verrucosa Stokes
6
Trachelomonas volvocina Ehrenb.
21, 114
Trachelomonas zingeri Roll
21, 114
Trachelomonas spp.
6, 20, 22, 23, 39, 124

Haptophyta[32]
Haptophyceae
Isochrysidales
Derepyxis amorpha Stokes
20
Derepyxis ovatum (Wislouch) Bourrelly
5, 20, 21
Derepyxis spp.
20, 121, 124, 126
Rhipidodendron huxleyi Kent
5, 21, 114
Rhipidodendron sp.
124
Spongomonas uvella Stein
21, 114

Pyrrophyta
Dinophyceae
Dinococcales
Cystodinium sp.
20

Hypnodinium sphaericum(33) Klebs
20, 21
Stylodinium spp.
20

Peridinales

Amphidinium spp.
76
Ceratium carolinianum (Bail.) Jørg.
5, 20, 21, 109, 110, 112, 114, 124
Ceratium hirundinella (O.F. Müll.) Duj.
1, 5, 20, 21, 22, 23, 24, 25, 27, 28, 29, 31, 88, 94, 98, 99, 100, 109, 110, 111, 112, 114, 124
Ceratium spp.
20, 22, 39, 95
Dinosphaera palustris (Lemm.) Kofoid & Michener
=*Gonyaulax palustris* Lemm.
100 (*G. palustre*)
Glenodinium armatum Levander
121
Glenodinium inaequale Chodat
21
Glenodinium pulvisculus (Ehrenb.) Stein
78, 97
=*Peridinium pulvisculus* Ehrenb.
118
Glenodinium spp.
20, 22, 39, 118
Gonyaulax spp.
20
Gymnodinium aeruginosum Stein
21, 97, 114
Gymnodinium cnecoides Harris
=*G. luteofaba* Javornicky
76, 77
Gymnodinium fuscum (Ehrenb.) Stein
20, 21, 114
=*G. caudatum* Prescott
76 (*G. caudata*)
Gymnodinium helveticum Pénard
76
Gymnodinium uberrimum (Allman) Kofoid & Swezy
=*G. rotundatum* Klebs
20, 21
Gymnodinium varians Maskell
76, 77, 118, 121
Gymnodinium spp.
1, 20, 22, 27, 28, 39, 76, 88, 110, 112, 118, 124
Hemidinium nasutum Stein
21, 114
Peridiniopsis balticum (Levander) Bourrelly
=*Glenodinium dybowskii* (Wolosz.) Lindem.
129
Peridiniopsis dinobryonis (Wolosz.) Bourrelly
=*Glenodinium dinobryonis* (Wolosz.) Schiller
5
Peridinium aciculiferum Lemm.
1, 76, 77, 88, 98, 118
Peridinium africanum Lemm.
114
Peridinium bipes Stein
5, 116, 124
Peridinium cinctum (O.F. Müll.) Ehrenb.
20, 21, 24, 25, 88, 97, 110, 112, 114, 116, 118, 124, 129
=*P. cinctum* f. *angulatum* (Lindem) Lefèvre
21, 114
=*P. cinctum* var. *tuberosum* (Meunier) Lindem
5, 21, 114, 124
Peridinium cinctum f. *irregulatum* (Lindem) Lefèvre
21, 114
Peridinium gatunense Nyg.
5, 114
Peridinium limbatum (Stokes) Lemm.
5
Peridinium palatinum Lauterb.
124
Peridinium raciborskii Wolosz.
=*P. palustre* (Lindem) Lefèvre
5, 21
Peridinium umbonatum Stein
=*P. inconspicuum* Lemm.
20, 21, 27, 28, 77, 106, 109, 110, 112, 114, 124
=*P. inconspicuum* var. *armatum* Lemm.
5
=*P. pusillum* (Pénard) Lemm.
20, 21, 99, 117, 118, 124
=*P. umbonatum* var. *inaequale* Lemm.
21, 114
Peridinium umbonatum var. *goslaviense* (Wolosz.) Popovsky & Pfiester
=*P. goslaviense* Wolosz.
77
Peridinium willei Huitfeld-Kaas
29, 98, 99, 124
=*P. volzii* Lemm.
1, 21, 88
=*P. striolatum* Wailes
100
Peridinium willei f. *sphaericum* Lindem
114
Peridinium willei f. *stagnale* Lindem
21
Peridinium wisconsinense Eddy
20, 21, 110, 112, 114
Peridinium spp.
1, 20, 22, 23, 29, 39, 76, 78, 99, 106, 116, 117, 118, 121, 124, 125, 126
Pulvisculus sp.
78
Sphaerodinium cinctum (Ehrenb.) Wolosz.
=*Glenodinium cinctum* (O.F. Müll.) Ehrenb.
100
Woloszynskia neglecta (Schilling) Thompson
=*Gymnodinium neglectum* (Schilling) Lindem
21, 114
Woloszynskia pascheri (Suchlandt) von Stosch
=*Gymnodinium veris* Lindem
118

Raphidophyta
Raphidophyceae
Raphidomonadales

Gonyostomum semen (Ehrenb.) Diesing
20, 21, 114
Vacuolaria virescens Cienkowski
21, 114

Rhodophyta
Bangiophyceae
Porphyridiales

Kyliniella lativca Skuja
5, 121

Florideophyceae
Batrachospermales

Batrachospermum boryanum Sirodot
36, 37, 38
Batrachospermum keratophytum Bory
=*B. vagum* (Roth) Ag.
5, 20, 37, 97
Batrachospermum sirodotii Skuja ex Reis
38
Batrachospermum spp.
20, 94, 100, 121
Lemanea borealis Atkinson
127
Lemanea fluviatilis (L.) Ag.
=*L. torulosa* Kütz.
97
Lemanea sp.
20
Sirodotia suecica Kylin
38
Tuomeya americana (Kütz.) Papenf.
20
=*T. fluviatilis* Harvey
5, 8, 11, 36, 37, 38, 128

Ceramiales

Ptilothamnion sp.
121

Nemaliales

Audouinella hermannii (Roth) Duby
=*A. violacea* (Kütz.) Hamel
36, 37
Audouinella sp.
97 (*Chantransia scotica* Kütz.[34])

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Appendice

[1]Le genre *Draparnaldia* a été revu en suivant le travail de Forest (1956).

[2]Le genre *Ankistrodesmus* a été revu à la lumière des travaux de Komárkova-Legnerová (1969) et de Komárek & Fott (1983).

[3]Selon Komárek & Fott (1983), ce taxon montre une certaine affinité avec les espèces du genre *Pseudoquadrigula* Lacoste de Diaz.

[4]Le genre *Characium* a été revu à la lumière des travaux de Komárek & Fott (1983).

[5]Selon Ettl (1978), *Characium naegelii* est en synonymie de *Characiopsis naegelii* (A. Br.) Lemm., mais nous préférons pour l'instant suivre Komárek & Fott (1983) et l'inclure sous *Characium conicum*.

[6]Selon Ettl (1978), *Characium ambiguum* est un synonyme de *Characiopsis minuta* (A. Br.) Lemm., mais nous préférons pour l'instant suivre Komárek & Fott (1983) et l'inclure sous *Characium ensiforme*.

[7]Selon Komárek & Fott (1983), ce taxon est d'une part un synonyme de *Characium rostratum* Rabenh. ex Printz *sensu* Prescott et d'autre part il est en synonymie de *Hydrianum ovale* Rabenh.; puisque les références utilisées au moment de l'identification nous sont inconnues et afin d'éviter toute confusion, nous préférons conserver ce taxon.

[8]Le genre *Monoraphidium* a été revu à la lumière des travaux de Komárkova-Legnerová (1969) et de Komárek & Fott (1983).

[9]Selon Ley (communication personelle), *Oophila amblystomatis* Lamb. ex Printz correspondrait peut-être à un stade de développement d'une autre algue et devrait être considérée comme un *nomen nudum*.

[10]Les travaux de Komárek & Fott (1983) et d'Hegewald & Silva (1988) ont été consultés en rapport avec le genre *Scenedesmus*.

[11]Selon Hegewald & Silva (1988), ce nom est illégitime.

[12]L'ouvrage de Mrozinska (1985) a été consulté pour les Oedogoniales.

[13]Les travaux d'Ettl & Gärtner (1988) ont été suivis pour les Tetrasporales.

[14]D'après Komárek & Fott (1983) et Ettl & Gärtner (1988), *Schizochlamis compacta* serait vraisemblablement une espèce du genre *Thorakochloris* Pascher.

[15]Selon Prescott et al. (1975), il serait injustifié d'utiliser l'épithète *sigmoideum* proposée par Irénée-Marie pour décrire de nouvelles formes puisqu'elles ne représentent en réalité que des variants écologiques et, par conséquent, elles sont considérées ici même comme des synonymes.

[16] Ce nom est illégitime car le taxon n'a jamais été publié, mais il apparaît tout de même dans l'index taxonomique du professeur Jules Brunel de l'Université de Montréal.

[17]Irénée-Marie (1938) et Prescott et al. (1977) acceptent ce synonyme alors que dans la litérature ce taxon est aussi considéré en synonymie sous *Cosmarium subdepressum*.

[18]La classification suivie des Bacillariophyta est celle récemment proposée par Round et al. (1990).

[19]D'après Håkansson (Krammer & Lange-Bertalot 1991), ce taxon pose plusieurs questions d'ordre nomenclatural et taxonomique et sa validité en tant qu'espèce est rejetée; en Amérique du Nord, très souvent des erreurs d'identification ont conduit à l'utilisation de *Stephanodiscus astraea* au lieu de *S. niagarae*.

[20]La variété nominale a déjà été transférée et se retrouve maintenant en synonymie sous *Fragilaria capucina* var. *rumpens*, mais pour l'instant, nous préférons conserver ce taxon en attendant une étude plus détaillée.

[21]*Eunotia clevei* Grunow in Cleve & Möller (1878) devrait être considéré comme un *nomen nudum* puisque la liste floristique rapporte ce taxon mais sans toutefois inclure une description ou une illustration si bien que l'auteur légitime devrait être Cleve (1891).

[22]L'auteur légitime du basionyme, *Cymbella incerta*, devrait être Cleve (1894) et non pas *C.* (*pisciculus* Greg. v.) *incerta* Grunow in Cleve & Möller (1878) lequel devrait être considéré comme un *nomen nudum* puisqu'aucune description ni illustration n'est rapportée dans la liste floristique.

[23]Taxon apparemment rarement présent en eau douce quoique retrouvé en condition électrolytique élevée.

[24]Grunow in Van Heurck (1880) a modifié l'orthographe de l'épithète spécifique *Navicula brauniana*, originellement décrite dans Schmidt (1876), en *Navicula braunii*; le nom correct à retenir est donc *Pinnularia brauniana*.

[25]Il semble que selon Krammer & Lange-Bertalot (1988), ce taxon est *Surirella minuta* Bréb. pro parte, *S. brebissonii* Krammer & Lange-Bertalot var. *brebissonii* pro parte et *S. brebissonii* var. *kuetzingii* Krammer & Lange-Bertalot pro parte.

[26]La classification suivie pour les Chrysophyceae est principalement celle de Starmach (1985).

[27]L'orthographe originale du nom de ce genre est *Bicosoeca* et tout taxon utilisant l'autre appellation, *Bicoeca*, sera placé en synonymie.

[28]Les travaux d'Ettl (1978) et Rieth (1980) ont été consultés pour les Xanthophyceae.

[29]L'ouvrage de Fott (1968) a été consulté pour les Cryptophyta.

[30]Les travaux de Desikachary (1959) et Bourrelly (1985) ont été consultés en rapport avec les Chamaesiphonales et les Chroococcales (Cyanophyta).

[31]Les travaux d'Huber-Pestalozzi (1955) et Compère (1989) ont été consultés pour les Euglenophyta.

[32]Les Haptophyta ont été revus à la lumière de l'étude de Starmach (1985).

[33]D'après Popovsky & Pfiester (1990), ce taxon serait peut-être une spore de résistance d'une autre dinoflagellée.

[34]*Chantransia scotica* Kützing correspondrait possiblement à un stade de développement d'une espèce du genre *Audouinella*.

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Notes

New Information on the Problem of Asiatic Cress, *Rorippa crystallina* Rollins (Brassicaceae)

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Mulligan, Gerald A., and William J. Cody. 1995. New information on the problem of Asiatic Cress, *Rorippa crystallina* Rollins (Brassicaceae). Canadian Field-Naturalist 109(1): 111–112.

Rorippa crystallina Rollins is transferred to *Nasturtium crystallinum* (Rollins) G. Mulligan, *comb. nov.* It is not native to North America but is introduced, probably from Asia as a cultivated plant, and has become naturalized locally in the Great Slave Lake region of the District of Mackenzie, Northwest Territories. We have therefore given it the common name Asiatic Cress. The specific name of this taxon is a misnomer. It was based on supposed calcium oxalate crystals in its inner tissues. However, the crystals on the type material are of formaldehyde, the specimen preservative used by the original collectors Thieret and Reich. *Nasturtium crystallinum* has the chromosome number of 2n = 32.

Key Words: Asiatic Cress, *Rorippa crystallina*, new combination, *Nasturtium crystallinum*, District of Mackenzie, Northwest Territories.

Rollins (1962) described a new species of mustard from the Great Slave region of the District of Mackenzie, Northwest Territories, Canada, as *Rorippa crystallina* Rollins. All of the material that he saw was collected from a localized area between mile 16.5N and mile 35N along the Mackenzie River-Yellowknife Highway by John W. Thieret and Robert J. Reich in 1961. This taxon is a persistent perennial with thick, fleshy roots. Its basal leaves are crenate to deeply lobed, with petals white, tinged with pink at their base, 6 to 8 mm long and 3 to 4.5 mm wide, and siliques semiterete, 15 to 25 mm long and 1.5 to 2.0 mm wide, with nearly nerveless valves. The seeds are uniseriate in the siliques and cotyledons are accumbent.

While G.A.M. was reviewing mustards for a proposed *Brassicaceae of Canada and Alaska*, it became evident that *Rorippa crystallina* is much closer to *Nasturtium officinale* R. Br., the type of the genus *Nasturtium* R. Br. (W. & W.T. Aiton, Hort. Kew. ed. 2, 4:109.1812, *nom. cons.*) than it is to *Rorippa* Scop. (Enum. Pl. 27.1822). *Nasturtium officinale* and *N. microphyllum* (Boenn.) Reicheb. both have white to pale pink flowers, semiterete siliques 13 to 22 mm long with valves nearly nerveless, seeds nearly uniseriate to biseriate, and cotyledons accumbent. Unlike *R. crystallina*, both of these are aquatic or semi-aquatic with creeping or floating stems that root at the nodes. Since all other known species of *Rorippa* in America, Europe and the (former) USSR have yellow petals, fruit a short silique or silicle and seed in two irregular rows, *R. crystallina* is here transferred to the genus *Nasturtium*, where it seems to have the closest affinity.

Nasturtium crystallinum (Rollins) G. Mulligan, **comb. nov.**, based on *Rorippa crystallina* Rollins, Rhodora 64: 326. 1962.

Stuckey (1972) stated that, "*R. crystallina* has a morphological close relationship to *Nasturtium barbareaefolium* Franchet (Bull. Bot. Soc. Fr. 33: 396.1888) of China". However this is an illegitimate later homonym of *Nasturtium barbareaefolium* Baker (Fl. Mauritius & Seychelles 7.1877). Stuckey examined two collections of the Franchet taxon from Yunnan and Szechwan in China and concluded that they were similar in overall appearance of the siliques and seeds to *R. crystallina*. Although, Franchet's taxon differed from *R. crystallina* by its shorter and ascending to appressed pedicels, he felt that *R. crystallina* is related to Asiatic *Nasturtium*, not American *Rorippa*. However, we do not know of a legitimate Asiatic name for our problem taxon. A search of the European literature including *Flora Europaea* (Heywood *in* Tutin et al. 1964) failed to reveal a taxon that is comparable to *Nasturtium crystallinum*. Dr. Victor Botscharzev of the Komarov Institute, in personal correspondence dated 18 April 1969, stated that *R. crystallina* did not occur in the (former) USSR, and that it was doubtful if it should be included in the genus *Rorippa*.

Cody collected herbarium and living material of our taxon from the type area of *Rorippa crystallina*

in 1965. He found that the local area where *Nasturtium crystallinum* was collected is a glaciated region and is not the habitat of any known endemics (see Porsild and Cody 1980). In addition, the area was farmed by a religious community for many years. We believe that *Nasturtium crystallinum* was introduced from an Asiatic source, possibly China, as a cultivated plant and has now become naturalized locally. Fresh leaves and roots have a pleasant cabbage-taste. We therefore have coined the common name Asiatic Cress for it.

Rollins (1962) based his specific epithet of *crystallina* on the supposed presence of calcium oxalate in the inner tissues of the specimens that he examined. However, the crystals in the material that he saw were of formaldehyde, the specimen preservative used by Thieret and Reich. Other herbarium and living material did not contain either formaldehyde nor calcium oxalate crystals.

The living material collected by Cody in 1965 had 32 somatic chromosomes (voucher, *W. J. Cody 14789*, DAO). Both *Rorippa* and *Nasturtium* have the basic chromosome number of $x = 8$.

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Predation of Thick-billed Murres, *Uria lomvia*, at Two Breeding Colonies by Polar Bears, *Ursus maritimus*, and Walruses, *Odobenus rosmarus*

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Donaldson, G. M., G. Chapdelaine, and J. D. Andrews. 1995. Predation of Thick-billed Murres, *Uria lomvia*, at two breeding colonies by Polar Bears, *Ursus maritimus*, and Walruses, *Odobenus rosmarus*. Canadian Field-Naturalist 109(1): 112–114.

Observations of Polar Bear (*Ursus maritimus*) predation at Thick-billed Murre *(Uria lomvia)* colonies at Coats and Akpatok Islands, Northwest Territories, during the summer months are documented. Hunting and predation by Walruses (*Odobenus rosmarus*) at Coats Island are also described.

Key Words: Thick-billed Murre, *Uria lomvia*, breeding colonies, Polar Bears, *Ursus maritimus*, Walrus, *Odobenus rosmarus*, predation, Coats Island, Akpatok Island, Northwest Territories.

Thick-billed Murres *(Uria lomvia)*, breed on cliff habitat at colonies found at high latitudes throughout the northern hemisphere. Predation of adults at the colonies during the summer breeding season is mainly by Arctic Foxes (*Alopex lagopus*), on accessible sites on the periphery of the colony, and at some colonies by Gyrfalcons (*Falco rusticolus*), generally around the colony. Eggs and chicks are also known to be depredated by Arctic Fox, Glaucous Gull (*Larus hyperboreus*), Iceland Gull (*Larus glaucoides*) and Common Raven (*Corvus corax*), the latter focusing primarily on eggs (Tuck 1960; Gaston et al. 1985). The amount of predation by these species is small; for example, at the murre colony on East Digges Island, adult mortality due to predation by Arctic Fox and Gyrfalcon has been estimated at less than one percent of the total population in a given year.

In areas where the annual ice melts completely during summer, Polar Bears are forced onto land where they may fast for up to four months (Stirling et al. 1977). While on land during the summer, bears have been known to consume a wide variety of food items including vegetation, marine algae, marine invertebrates, small mammals, and birds (Russell 1975; Derocher et al. 1993). However, observations and stable-carbon isotope analysis suggested that during the ice-free period bears subsist primarily on fat reserves (Russell 1975; Knudsen 1978; Latour 1981; Ramsay and Hobson 1991).

Predation by larger mammals has not been recorded previously at seabird colonies in Arctic Canada. Here, we report observations of Polar Bears (*Ursus maritimus*) and Walruses (*Odobenus rosmarus*) feeding on Thick-billed Murres at Coats Island and Akpatok Island, Northwest Territories.

Methods

The Canadian Wildlife Service has been monitoring the Thick-billed Murre colony near Cape Pembroke on Coats Island (62°57'N, 82°00'W) in northern Hudson Bay during the summer annually since 1984. Observations pertaining to the natural history of the area around the colony were recorded daily during the course of each field season. Similar observations were recorded at the colony at the northern tip of Akpatok Island in early September 1993.

Results

Between 1984 and 1993, bears were recorded near the Coats Island colony in all but two years (Gaston 1991; G. Donaldson personal observation). The majority were passing by on land or in the sea. Only two bears were observed interacting directly with murres from the colony.

On 13 August 1991, one adult bear was observed swimming into the cove in which the west sub-colony of murres was located. The bear approached the raft of murres that is often present below the colony at that time of year, dove under the surface of the water and came up underneath a single murre. It captured the murre in its jaws with the help of its forepaw and took the bird to a nearby island where it was consumed in its entirety. Polar Bears swimming in the vicinity of Thick-billed Murres have been observed at Coats Island and elsewhere on four other occasions, but no attempts at predation were seen (A. J. Gaston, personal observation).

In early July 1992, a female bear with two yearling cubs entered the colony cove on the landfast ice that is usually present at that time of year. When land fast ice is present below the colonies, some murres cannot gain flight from the surface of the ice and must walk to open water in a lead or at the floe edge where they may take off (G. Donaldson, personal observation). At this time, murres are extremely vulnerable to predation as their progress on the ice can be slow; dozens are killed each year at Coats Isalnd by Arctic Foxes. It was not certain whether this Polar Bear killed a murre or if she scavenged a fox kill, but a murre carcass was delivered to her cubs after which she began to hunt by remaining motionless at a seal breathing hole approximately 100 m away. The murre was dismembered and eaten by her cubs (G. Donaldson, personal observation).

Predation of murres by Polar Bears was also observed at the Thick-billed Murre colony at the northern end of Akpatok Island (60°34'N, 68°00'W) in Ungava Bay. The colony at Akpatok Island has an extensive beach at low tide where murres may land and then have to walk to the sea in order to gain flight. During a two-week visit in early September 1993, bears were seen on the beach at the front of the colony on all but a few days. A minimum number of five bears was present including a female with two cubs and at least one male. Most sightings were made at Hell Cliff where the largest concentrations of murres were found. No birds were observed being caught but Polar Bear scats containing murre feathers were common, as were murre carcasses stripped of flesh. Exact numbers of birds being caught were difficult to estimate because the carcasses were washed away at high tide. Of the carcasses discovered, some had only the breast muscle missing; others were more completely consumed with only wings and keel remaining. The condition of the carcasses precluded predation by Arctic Foxes, none of which were seen during the two-week period. A second, smaller Thick-billed Murre colony is located at the southern end of Akpatok Island. During a circumnavigation of the island by Twin Otter in mid-September 1993, a female with two cubs was observed there in addition to the family group present at the north colony.

At Coats Island, a Walrus was observed making several attempts to capture Thick-billed Murres in the cove below the west sub-colony by swimming up beneath them. Each time the murres escaped on the wave created by the surfacing animal and no successful predations were recorded. The same Walrus caught two murre chicks by pulling them beneath the surface of the water after they had become separated from their accompanying parent after fledging (J. D. Andrews, personal observation). In June 1994, a Walrus was similarly seen attempting unsucessfully to take adult murres by surfacing beneath them (K. Kampp, personal communication).

Discussion

If most bears have built up sufficient fat reserves in the spring to carry them through the summer, murres may not be desirable prey because they are low in fat, compared to seals, and are only available in large numbers at the colonies at a time of the year

when most bears are fat and not usually feeding. Lunn and Stirling (1985) showed that bears hunting Snow Geese (*Anser caerulescens*) would probably spend more energy hunting than would be gained by consuming a goose; the same is probably true of Thick-billed Murres. Bears in need of food at this time of year are more likely to hunt at one of the many Walrus haulouts located on the northern coast of Coats Island. Two days prior to the observation of a bear predation on a murre, three Walrus carcasses were seen at a haulout 10 km east of the colony. Of the three, two were fresh indicating some feeding on Walrus by bears on Coats Island in the summer months. In July 1994, a Polar Bear was seen carrying a freshly killed Walrus pup in the same area (A. J. Gaston, personal communication).

Ungava Bay lacks large concentrations of alternate prey for bears during summer, such as the Walruses on Coats Island or the vegetation that bears in western Hudson Bay may feed on. Polar Bears in this area may be attracted to the large seabird colonies on Akpatok Island as a consequence. It is possible that the high energy requirements of lactation require females to feed more during the summer months than males of comparable size and may explain why females with cubs were present at both colonies at Akpatok Island.

Walruses feed primarily on bivalves (Fay 1982; Reidman 1990) but may occasionally feed on fish and seals (Fay 1982). Examination of the stomach contents of a Walrus collected in the Bering Sea revealed the remains of a Black Guillemot *(Cepphus grylle)* indicating that Walruses may infrequently feed on seabirds (Fay and Merrik 1990). In the Southern Hemisphere, penguins are regularly predated by pinipeds such as Sea Lions (*Otaria flavescens*), Leopard Seals (*Hydrurga leptonyx*), and Fur Seals (*Arctocephalus gazella*) (Reidman 1990). Our observations indicate that pinnipeds in the eastern Arctic also prey occasionally on local seabird communities.

Despite many field seasons of observations at the Coats Island colony, only a few depredation events have been recorded for either Polar Bears or Walruses. Although these events probably occur more frequently than our observations imply, Thick-billed Murres do not make up a significant proportion of the diet of the two predators. Because of the low frequency of occurrence, this predation does not exert a significant influence on murre populations. These observations are important to a better understanding of trophic dynamics in the Arctic marine environment by improving knowledge with respect to prey items available to both Polar Bears and Walruses.

Acknowledgments

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Bald Eagle, *Haliaeetus leucocephalus*, and Northern Goshawk, *Accipiter gentilis*, Nests Apparently Preyed upon by a Wolverine(s), *Gulo gulo*, in the Southwestern Yukon Territory

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Doyle, F. I. 1995. Bald Eagle, *Haliaeetus leucocephalus*, and Northern Goshawk, *Accipiter gentilis*, nests apparently preyed upon by Wolverine(s), *Gulo gulo*, in the southwestern Yukon Territory. Canadian Field-Naturalist 109(1):115–116.

I present evidence of apparent Wolverine (*Gulo gulo*) predation on one Bald Eagle (*Haliaeetus leucocephalus*) and one Northern Goshawk (*Accipiter gentilis*) nest in Kluane Lake area of the Yukon Territory.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, Northern Goshawk, *Accipiter gentilis*, Wolverine, *Gulo gulo*, guard hairs, Yukon Territory.

An understanding of the linkages between trophic levels is important in understanding any ecosystem. Here I describe an unexpected linkage between a mammalian predator/scavenger and two different avian predator species. There are no previously documented cases of Wolverines (*Gulo gulo*) preying upon raptor nestlings.

At Kluane Lake in the southwestern Yukon Territory, Canada, studies of the raptor community have been underway since 1986, as part of a larger project looking at the ecosystem of the boreal forest (Krebs et al. 1986, 1992). A total of 278 raptor nests have so far been monitored, 20 were of Northern Goshawk, *Accipiter gentilis*, and 10 were of Bald Eagle (*Haliaeetus leucocephalus*).

On 10 July 1992, an adult Bald Eagle was circling and calling around a nest site previously used in 1990 and 1991. The nest was situated 1 m from the top of a 13 m high mature White Spruce (*Picea glauca*) in a semi-open area of mature spruce and Trembling Aspen (*Populus tremuloides*) forest, 500 m from open water. Two downy chicks were visible in the nest at that time. When I revisited the site on 17 July, no adults were present and the remains of one dead chick were found lying on the forest floor 5 m from the base of the nest tree. Another chick was found dead on a branch 2 m beneath the nest, and a third was dead in the nest. A fresh Wolverine scat was found at the base of the nest tree, and a close inspection of the bark revealed mammalian guard hairs all the way up the trunk of the tree and on the edge of the nest. Broken branches, claw marks, and down from a chick were also visible along the same route.

Wolverines are known to be excellent climbers (Banfield 1974), and the guard hairs found on the trunk of the tree were identified as Wolverine when the characteristics of the hair were examined under a compound microscope. The hairs of Wolverine are at least 65 mm long, longer than those of any other Mustelidae, and have a characteristic black tip 5-15 mm long. The maximum guard hair length of other Mustelidae found in our area is 36 mm (Moore et al. 1974). The guard hairs collected from the trunk of the tree were all 65-80 mm long.

The chick in the nest had a broken femur and sternum, but had not been eaten. The chick on the branch 2 m below the nest was intact. Both chicks were maggot ridden, and it was not possible to see any flesh wounds. Only feathers and small pieces of femur and vertebrae remained of the chick on the forest floor. The feathers were chewed and ripped off in chunks, and down and feathers were spread over a 1 x 2 m area. The small pieces of bone had been broken and chewed. The remains looked fresh, but had been washed by rain. The most recent rainfall was on 15 July. All chicks appeared to be the same age, and the two whole chicks in the nest tree were at the same stage of decomposition. Chick appearance, feather development and length of the 8th primaries indicated that the chicks were about 50 days old (Bortolotti 1984).

The other apparent case of Wolverine predation occurred 30 km away at a Northern Goshawk nest. The nest was discovered on 13 May 1991, in a semi-open stand of mixed-age White Spruce at the base of a 25-m high grass-covered glacial moraine. The nest was situated against the trunk on a 30 cm wide clump of Witches Broom (*Chrysomyxa, arctostaphi*), 2 m from the top of a 10 m high White Spruce. This was a new nest, but a pair of goshawks had nested 150 m away in the previous year, successfully fledging four young.

Weekly checks were made on the nest, to monitor its progress and to remove prey remains and pellets from around the base of the nest. On 17 June, chicks could be heard begging from the nest as the area was approached, and the adult female swooped at me as I searched for pellets and prey remains 50 m from the nest.

The nest was revisited on 26 June and no chicks or adults were present. Twenty immature pin-feathers were found at the base of the nest tree. These were

scattered over 2 m, and had been chewed. Claw marks were observed on the tree and Wolverine guard hairs were found lodged in the bark of the trunk beneath the nest. The nest was empty and intact. Evidence suggested the three-week-old chicks (based on the length of primary feathers compared to nestlings of known age) had been killed by a Wolverine.

Are there any common factors in the nesting ecology of these two species which would have made them susceptible to predation by Wolverines? One characteristic of both raptors is the presence of prey remains on the forest floor around their nest area which could attract predators. Beneath Bald Eagle nests, fish and bird remains are often found (Hunt et al 1992), and Northern Goshawks pluck and often leave prey remains on the forest floor around the nest (Widen 1987). Do these traits make these species more vulnerable to encounters with Wolverines ?

Sharp-shinned Hawk (*Accipiter striatus*), also leave prey remains on the ground around the nest area (Reynolds and Meslow 1984). Four Sharp-shinned Hawk nests were located in our study area, and all successfully fledged young. Northern Harriers (*Circus cyaneus*) may also be vulnerable, with prey remains often found in and around the nest (Errington 1932). Seventeen Northern Harrier nests have also been monitored, and two were preyed upon by mammals, but no fur or other sign was present to indicate the identity of the predator.

Of the other species monitored, Great Horned Owl (*Bubo virginianus*), Northern Hawk Owl (*Surina uluna*), Red-tailed Hawk (*Buteo jamaicensis harlani*) and American Kestrel (*Falco sparverius*), only one of 227 nests, that of a Great Horned Owl, was predated by a mammalian predator. No fur was collected from the site, but a scat containing owl remains was found at the base of the nest tree. The shape of the scat indicated it had been made by a Wolverine.

These apparent cases of predation by Wolverine(s) may be isolated incidents. I can find no similar reports for this circumpolar species (Wilson 1982). It was, however, only with very close inspection of the nest tree that the identity of the predator was revealed. These signs might easily have been overlooked, suggesting that this sort of predation may not be as uncommon as we think.

Acknowledgments

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Grizzly Bear, *Ursus arctos*, – Wolf, *Canis lupus*, Interaction in Glacier National Park, Montana

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Kehoe, Nancy M. 1995. Grizzly Bear, *Ursus arctos* – Wolf, *Canis lupus*, interaction in Glacier National Park, Montana. Canadian Field-Naturalist 109(1): 117–118.

Agonistic behavior between a Grizzly Bear (*Ursus arctos horribilis*) with its cub and a large pack of Wolves (*Canis lupus*) was observed during an overflight of Glacier National Park in northwestern Montana (ca. 48° 41′N, 114° 09′W). The Wolves pursued and bit the adult bear as the animals moved along the edge of a meadow used as a natal den by the Wolves. The adult bear responded to the attack by repeatedly swatting at and charging the Wolves. At one point, several Wolves chased and attacked the cub, provoking an immediate defense response by the female bear. Direct, interspecific aggression between Grizzly Bears and Wolves in the conterminous 48 states, where the species are listed respectively as threatened and endangered, may impact either or both of these recovering populations.

Key Words: Grizzly Bear, *Ursus arctos*, Wolf, *Canis lupus*, bear-wolf interaction, interspecific aggression, Flathead River valley, Glacier National Park, Montana.

Published accounts of direct interactions between Grizzly Bears (*Ursus arctos*) and Wolves (*Canis lupus*) indicate that competition for carcasses and defense of young are primary factors (Murie 1944; Ballard 1982; Hornbeck and Horejsi 1986). Direct, interspecific aggression between Grizzly Bears or Black Bears (*Ursus americanus*) and Wolves has resulted in mortality to Wolves (Pimlott et al. 1969; Ballard 1980) and to bears (Ballard 1982; Paquet and Carbyn 1986; Lavov cited by Servheen and Knight 1990). Rogers and Mech (1981) reported a nine-member Wolf pack killing a 16-year-old female Black Bear and her two newborn cubs. The impacts of such encounters on Wolf and bear populations are unknown. In the northwestern United States, where Grizzly Bear and Wolf populations are listed respectively as threatened and endangered, the potential impacts of interspecific aggression may be important considerations for conservation and reintroduction efforts.

Description of Observation

The following incident took place during a Grizzly Bear radiotelemetry flight conducted in a Cessna 182. The area, located close to the western edge of Glacier National Park, consists of conifer forest dominated by Ponderosa Pine (*Pinus ponderosa*) and Douglas Fir (*Pseudostuga menzeisii*) surrounding large, dry meadows. There was no snow on the ground or vegetation.

At 1000 h on 25 October 1993 the pilot and I were flying eastward, homing in on a male Grizzly Bear in Glacier National Park. As we flew towards the bear, we observed two dark animals approximately 2 km away, moving through the grass on the southeast edge of a large meadow. Wolves recolonizing the North Fork drainage used this area as a natal den site during 1993 (Pletscher, personal communication). The larger animal, a bear, was 1-2 m ahead of the other, a Wolf or bear cub, as the animals trotted southward.

As we approached, we discerned additional animals in the group. We were unable to keep the smaller of the two animals initially observed visually separated from the mass of animals moving below. Our first close, unobscured view of the group revealed a pack of 17 or 18 Wolves chasing a large, dark Grizzly Bear. A few Wolves ran alongside the bear, several more were grouped directly behind it, and the rest were strung out single file on a trail in the meadow. The Wolves closest to the bear continually bit its rear legs and hindquarters as they trotted behind and alongside it. The bear responded by pausing periodically to turn and swat at the Wolves. The bear's paw came close to, but did not appear to contact, the Wolves. Several times the bear turned and charged a Wolf that had bitten it, chasing it up to 30 m. The bear moved off the path and ran upslope and into the trees at a point where the trail came close to the forest edge. This transitional forest area of conifers interspersed with patches of dried graminoids and bare deciduous shrubs was relatively open. After the bear came to a stop, the Wolves surrounded the bear and began to attack.

We circled approximately 100 m above ground level. We next observed the female walking at an angle upslope followed by the main group of Wolves. Several other Wolves were chasing single file after a Grizzly Bear cub running directly upslope and away from the female. In seconds the Wolves overtook, encircled, and bit the cub, tugging and shaking their heads. Other Wolves stood nearby but did not participate in the attack.

The female bear leapt over a log which separated her from her cub, scattering the Wolves and allowing the cub to jump up onto the log. The Wolves which had been chased off the cub briefly hesitated, not immediately following in pursuit. Our flight path

prevented us from observing what occurred as the cub ran upslope on the log.

As the scene below again came into view, the cub was out of sight and the Wolves which had been nearest it stood looking around in several directions. We searched the trees near the log and watched the Wolves for an indication of the cub's location, but there was no sign of the cub. A portion of the pack, approximately 8-10 animals, continued to harass the female bear, biting her from all sides. Appearing to tire, the bear slumped against the log. The log and a thorny shrub growing adjacent to it partially protected the bear and forced the Wolves, which were on the same side of the log and even with or downslope to her, to attack her frontally. For a few seconds the attack subsided. The Wolves moved upslope and resumed biting at her side and hindquarters.

When we circled back over the animals, the bear had left the protection of the log and was moving through the trees without her cub. The bear and entire Wolf pack resumed traveling southward, the Wolves biting the bear's hindquarters as the animals proceeded through the forest. After about 30 s, the bear and Wolves moved into a large stand of mature conifers with a dense canopy cover, precluding further observation.

Four days later I returned to the meadow on foot to search for signs indicating the outcome of the interaction. Wolf tracks, including scratches, were evident on the log that the cub had run up, indicating Wolves had crossed over the log just above the thorny bush. The steepness and slickness of the log and lack of tracks along it indicated that Wolves did not travel on the log except in crossing. I was unable to find any bear or Wolf scat, fur, blood, or other remains, and no sign of disturbed vegetation or soil in the adjacent forest area that would have indicated that a fight had occurred. No ungulate or other carcasses were observed in the area, either from the air on the date of the interaction or during the ground search.

Discussion

Recorded bear-Wolf interactions vary from tolerance both away from and at an ungulate carcass (Lent 1964) to a bear killing a Wolf (Ballard 1980) to a nine-member Wolf pack killing an adult female bear and her two cubs. Ballard (1982) reported two Wolves in south-central Alaska chasing and harassing a female Brown Bear with young, at one point treeing all three yearlings. It is possible that the retreating Grizzly Bear we observed, greatly outnumbered by the 17-18 Wolves, left her cub in a tree. Within three minutes of leaving the Wolf group, we radiolocated a 250 kg adult male Grizzly Bear approximately 150 m upslope from our last observation of the cub. This adult male gave no indication it was aware of the interaction nearby. If the cub was left unattended as it appeared, it could have been vulnerable to predation by either Wolves or the adult male. Grizzly Bear interactions with recolonizing Wolves in the contiguous 48 states have not been previously documented, and the effects of such interactions on the populations of each species are unknown.

Acknowledgments

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Cartwheeling Behaviour in the Broad-winged Hawk, *Buteo platypterus*

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Arndt, Janice E. 1995. Cartwheeling behaviour in the Broad-winged Hawk, *Buteo platypterus*. Canadian Field-Naturalist 109(1): 119–120.

I observed the aerial display of two Broad-winged Hawks, *Buteo platypterus*, in Fredericton, New Brunswick, which included circling, undulating flight, diving and cartwheeling. These behaviours occurred early in the breeding season and may have been related to courtship. Cartwheeling has not previously been reported for this species and does not occur regularly among other *Buteo* hawks.

Key Words: Broad-winged Hawk, *Buteo platypterus*, cartwheeling, aerial display, New Brunswick.

Many raptor species perform spectacular aerial displays that are associated with courtship, territorial advertisement or territorial defense. One behaviour pattern, referred to as whirling or cartwheeling (Johnsgard 1990), involves two birds meeting in mid-air, locking talons and falling earthward as they spiral around one another. Within the Falconiformes, cartwheeling has been reported in the genus *Falco* of the family Falconidae and in at least 19 genera of the family Accipitridae, including seven species of *Buteo* hawks. However, cartwheeling has not previously been described in the Broad-winged Hawk, *Buteo platypterus*.

The following observations occurred at the University of New Brunswick Forest in Fredericton, New Brunswick. At mid-day on 29 April 1993, while walking along the edge of a clear-cut area adjacent to Corbett Marsh (45°55′N, 66°39′W), I heard the calls of a Broad-winged Hawk and observed two birds soaring high above me. I noticed no behaviours other than soaring and calling, and the hawks flew out of sight. On 3 May 1993, at approximately 12:30, I was in the same location when I again heard Broad-winged Hawk calls. Two birds came into sight fairly low above the trees. Both birds called and appeared to fly in broad circles in opposite directions. At least one hawk performed undulating flight (a series of shallow swoops, as described by Brown and Amadon 1968) while the birds continued to call and circle. Because the hawks were still fairly low and my view of each was periodically obscured by trees, I could not determine if both birds exhibited this display. One bird gained altitude and executed a particularly steep dive. After several minutes, the birds approached one another and came close to touching. After parting momentarily, they came together again with talons out-stretched and made contact with each other. The hawks spiralled downward for approximately two rotations while connected by one foot, then released and parted. Although the birds had lost altitude, they separated well above the ground. Within seconds of parting the birds disappeared from my view.

Traditionally, cartwheeling in raptors has been ascribed almost exclusively to courtship behaviour (e.g., Brown and Amadon 1968). Recently, however, its behavioural significance has been regarded more critically (Johnsgard 1990; Simmons and Mendelsohn 1993), and several instances have been interpreted as agonistic interactions (e.g., Northern Harrier, *Circus cyaneus*, Craig et al. 1982; Zone-tailed Hawk, *B. albonotatus*, Clark 1984). Simmons and Mendelsohn (1993) assessed over 100 observations of cartwheeling among raptors and attempted to place each into context depending on such factors as the behaviour of the birds preceding or following cartwheeling, the time of year, and the age or sex of identifiable individuals. Based on their interpretations of these factors, Simmons and Mendelsohn (1993) argued that over 80% of the observations constituted aggressive interactions and that incidences of courtship were extremely rare. In my opinion, however, several instances that were reinterpreted as agonistic rather than courtship behaviour lacked sufficient details to classify unequivocally.

Among North American *Buteo* species, cartwheeling has been clearly demonstrated to occur in both the context of aggression and of courtship. For example, Kilham (1981; *as cited by* Johngard 1990) documented an interaction between Red-shouldered Hawks (*B. lineatus*) in which a territorial male locked talons and cartwheeled with an intruder. They separated close to the ground and the resident male returned to his mate a short time later. Conversely, Springer (1979) reported mutual diving, rolling and cartwheeling between a pair of Red-tailed Hawks (*B. jamaicensis*) which was followed by copulation.

In my observation of cartwheeling between two Broad-winged Hawks the sex of each bird was unknown, and their behaviour following cartwheeling was not observed, making a determination of its

significance difficult. The interaction occurred early in the breeding season when activities associated with courtship, territorial advertisement, and territorial defense could all be expected. Johnsgard (1990) stated that aerial display in raptors during this period may simultaneously or sequentially serve any of these functions, making it nearly impossible to separate courtship and territorial behaviour in many instances. For example, descriptions of both territorial interactions and courtship activities between Red-tailed Hawks included circling, calling and swooping (Fitch et al. 1946). Although such detailed information is not available for Broad-winged Hawks, the actions I observed prior to the cartwheeling were consistent with courtship behaviour described by Johnsgard (1990) as typical for this species, including mutual territorial advertisement associated with courtship display.

In addition to the criteria used by Mendelsohn and Simmons (1993) to judge cartwheeling flights, duration of contact may also provide an indication of an interaction's social significance. In a five-year experiment, about 90% of over 200 instances of agonistic cartwheeling in African Fish Eagles (*Haliaeetus vocifer*) induced by T. Liversedge (*in* Simmons and Mendelsohn 1993) ended with the birds separating only a few meters above the ground. In the remaining cases the eagles fell into water or reeds, and one death was noted. Cartwheeling flights that terminated in water or on the ground have also been reported in other species and have occasionally resulted in injury or death (Simmons and Mendelsohn 1993). This has led to speculation that in such instances the cartwheeling action results from each individual trying to gain the upper position as the attacking bird attempts to force the other to the ground (e.g., Simmons and Mendelsohn 1993). In contrast, cartwheeling in a courtship context is not expected to involve a risk of injury to either bird. In the same population of African Fish Eagles, Liversedge (*in* Simmons and Mendelsohn 1993) observed cartwheeling interactions between known mated pairs in which contact was maintained for only 2-3 rotations and the distance the birds fell did not approach that seen in territorial interactions. Similarly, courting Red-tailed Hawks cartwheeled for only approximately 3 sec (Springer 1979). The Broad-winged Hawks I observed were in contact with each other very briefly and separated well above the ground.

Although the behavioural significance of the cartwheeling interaction described above between two Broad-winged Hawks cannot be determined with absolute certainty, courtship seems a more likely interpretation than territorial aggression. Regardless of its function, this element of aerial display was not previously reported in Broad-winged Hawks and represents an addition to the list of species known to exhibit cartwheeling behaviour.

Acknowledgments

I thank S. K. A. Arndt, J. S. Marks and R. F. Stocek for helpful comments on the manuscript.

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Albino Eastern Screech-Owl, *Otus asio*

DENVER W. HOLT[1], MAUD W. ROBERTSON[2], and JOHN T. RICKS[3]

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Holt, Denver W., Maud W. Robertson, and John T. Ricks. 1995. Albino Eastern Screech-Owl, *Otus asio*. Canadian Field-Naturalist 109(1): 121–122.

An albino Eastern Screech-Owl (*Otus asio*), was observed on Long Island, New York from 1982 to 1987. The literature pertaining to coloration and albinism in owls indicates that albinism has only been reported in five other species of owls. Of these, only one Barred Owl (*Strix varia*) was considered to have total albino characteristics.

Key Words: Eastern Screech-Owl, *Otus asio*, albinism, owl coloration, New York.

Feather color in birds originates from the presence and structural arrangement of biochrome pigments (Gill 1990). The expression of these pigments is influenced by genetic and hormonal factors (Gill 1990). Three pigments are primarily responsible for biochrome colors in birds; melanins, porphyrins, and carotenoids. Melanins are the most common pigments, while porphyrins are relatively rare. Owls express monochromatic, dichromatic, or polychromatic feather coloration derived from biochrome pigments (Terres 1980). Most North American owls, however, show monochromatic coloration derived from melanins. Erythrism, an excess of reddish/brown pigment occurs in feathers of the reddish morphs; Eastern Screech-Owl (*Otus asio*), Western Screech-Owl (*O. kennicottii*), Flammulated Owl (*O. flammeolus*), and Northern Pygmy-Owl (*Glaucidium gnoma*). In Europe, the Scops Owl (*O. scops*) and Tawny Owl (*Strix aluco*) also have reddish morphs. This pigment is typically produced by melanins (Welty and Baptista 1988). The Eastern Screech-Owl is polymorphic, having red and gray morphs, and an uncommon intermediate color (Van Camp and Henny 1975). The red morph results from a dominant allele, whereas the gray morph arises from a recessive gene (Van Camp and Henney 1975). Adult Snowy Owls (*Nyctea scandiaca*), which are primarily white, have feather color derived from a schemochrome feather structure which possesses little or no pigment. Light reflects within the feather structure and produces the white coloration.

White plumage is not proof of albinism. Albinism in owls is rare, particulary true albinism (see Gross 1965). Albinism is derived from a recessive gene which inhibits the enzyme tyrosinase. Tyrosine, an amino acid, synthesises the melanin that is the basis of many avian colors. Albinism in birds has been separated into four categories (Mueller and Hutt 1941); (1) Total albinism — a simultaneous complete absence of melanin from the eyes, skin, and feathers: this is the rarest form; (2) Incomplete albinism — when melanin is not simultaneously absent from the eyes, skin and feathers; (3) Imperfect albinism — when melanin is reduced in the eyes, skin and feathers; and (4) Partial albinism — when albinism is localized to certain areas of the body. Partial albinism may result from injury, physiological disorders, diet, or circulatory problems, and is the type most frequently observed.

Here, we report a case of albinism in the Eastern Screech-Owl, from Huntington, Suffolk County, Long Island, New York. The area is suburban with small wood-lots surrounding homes. The habitat is mixed deciduous woods consisting mostly of dogwood (*Cornus* spp.), hickory (*Carya* spp.), maple (*Acer* spp.), and oak (*Quercus* spp.). The owl frequently roosted in a dead broken-sided tree, where MWR and JTR observed and photographed it intermittently from 1982 to 1987. The owl was white with few tan-colored contour feathers on the breast (see cover). The irises were pink, and the pupils black. The mandible, maxilla, and talons were yellow/white, and the toes pink.

In Ohio, Van Camp and Henny (1975) banded over 3000 Eastern Screech-Owls from 1944 to 1973 and reported no albinism. In Texas, Fred Gehlbach (personal communication) banded or observed 837 Eastern Screech-Owls from 1967 to 1993, and reported no albinism. We located only one report. In May 1968, one of two captured downy-feathered Eastern Screech-Owls from Garfield Park, Douglas County, Nebraska, was described as "pure white with pink eyes" (Schneider 1969), an apparent total abino. It was given to the Lincoln Childrens Zoo. On 7 November 1968, the owl was visited at the zoo and described again, but this time as being white with a few tan feathers on the breast and the eyes were "not pink now", but the "pupil" appeared redder than that of its nest mate (Bennett 1969). In Massachusetts, Norman Smith (personal communication) treated an injured Eastern Screech-Owl with "a few" white dorsal covert feathers on the left wing. Ross (1973) reviewed albinism in North American birds and reported a "complete" albino specimen Eastern Screech-Owl, but did not cite the origin of that report.

Albinism in birds is uncommon (Gross 1965). Of 1847 albino records, representing 54 families of 304 species in the United States and Canada, only 7.0% were total albinos (Gross 1965). Among owls, one total albino Barred Owl (*Strix varia*) was reported (Deane 1876). Other partial albinos include; Burrowing Owl (*Speotyto cunicularia*) (Sutton 1912); Great Horned Owl (*Bubo virginianus*) (Spofford 1952); Short-eared Owl (*Asio flammeus*) (Sage 1883); "2 or 3" Great Gray Owls (*Strix nebulosa*) presently in Yellowstone National Park (Terry McEneaney, personal communication.); and an adult and one young Western Screech-Owl observed in Washington (Terry Flemming, personal communication). Gross (1965) noted nine cases of albinism from five species of owls, but did not list the species or degree of albinism, and it is likely that some of the species of owls cited above were included in his report. The lack of pigmentation in the eyes of albinos appears to be the conclusive characteristic of total albinism (Mueller and Hutt 1941). Although our owl had few tan feathers on the breast, its eyes and toes were pink, and we conclude it best fits the total albino definition.

Albino organisms are thought to have a short life expectancy because the conspicuous nature of their color renders them more vulnerable to predation and intraspecific conflict. Physiological disorders can also be associated with albinism. It is likely that the Eastern Screech-Owl we report survived at least five years as only one albino was ever observed at a time. It was not known if this owl bred or its fate.

Acknowledgments

Rebecca Irwin, Ted Swem, and Michael Maples made helpful suggestions on the draft manuscript, and pointed us to pertinent literature. Adrian J. Dignan took the photograph.

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News and Comment

Amphipacifica: Volume 1, Number 4

Amphipacifica: Journal of Systematic Biology Volume 1, Number 4, was issued 30 January 1995 and contained two major articles: The amphipod superfamily Eusiroidea in the North American Pacific region. I. Family Eusiridae: systematics and distributional ecology. E. L. Bousfield and E. A. Hendrycks — pages 3-59; The amphipod genus *Paramoera* Miers (Grammaridea: Eusiroidea: Pontogeneiidae) in the eastern North Pacific. Craig P. Staude — pages 61-102.

In his *Editorial Commentary* for the issue (page 1) E. L. Bousfield points to a future potential flexibility in contents which will add to the journal's initial aim of publishing monographic treatments that are too large or bulky for acceptance in standard taxonomic journals: "We welcome submissions of short studies, as well as medium to long papers, and review articles that involve some aspect of aquatic biology and/or environmental concern. Although the journal focuses on aquatic invertebrates of the North Pacific, analytical accounts of other biotas (including vertebrates and fossil animals), of other biomes (including terrestrial), and other world regions are invited."

Information on subscription rates and instructions to authors can be obtained from Dr. E. L. Bousfield, Managing Editor, Amphipacifica Research Publications, 611-548 Dallas Road, Victoria, British Columbia, Canada V8V 1B3.

Amphipacifica, Volume 1, Supplement 1

Amphipacifica: Journal of Systematic Biology Volume 1, Supplement 1 (26 pages) was issued 20 April 1995 and contains, in addition to some editorial background and discussion of the positive and negative reviews of its contents, one article: An account of *Cadborosaurus willsi*, new genus, new species, a large aquatic reptile from the Pacific coast of North America by E. L. Bousfield and P. H. LeBlond.

Separate copies of this supplement at $5.00 Canadian ($4.00 U.S.) (postage included) are available from Dr. E. L. Bousfield, Managing Editor, Amphipacifica Research Publications, 611-548 Dallas Road, Victoria British Columbia, Canada V8V 1B3.

North American Butterfly Association

There are 720 species of butterflies found in North America and many are as available to visually-orientated study as birds. They tend to be most active when bird activity hits its lulls at mid-day and/or mid-summer. Because of the close association of individual species with specific plants, both as nectar sources for adults and forage for caterpillars, knowledge of local butterflies is a important aspect of a well-grounded naturalist.

Recently, The North American Butterfly Association (NABA), has formed as a non-profit group. It is the only continent-wide organization focused on recreational butterfly identification through binoculars and butterfly gardening. Its interests also include photography, species listing, and non-consumptive (e.g., netless) appreciation.

NABA publishes a quarterly color magazine *American Butterflies*, a newsletter *The Anglewing*, and conducts and publishes the annual 4th of July Butterfly Counts. Regular dues are U.S.$25 (U.S.$30 outside the U.S.). To join, of for more information, contact the NABA at the address below.

JEFFREY GLASSBERG

President, North American Butterfly Association, 4 Delaware Road, Morristown, New Jersey 07960 USA.

The Atlas of Breeding Birds of Alberta

Five years of field research by over 1000 volunteers are presented in a comprehensive atlas which covers the current distribution, status and preferred habitat of every nesting bird species in Alberta. It is 400 pages, 9.5 x 12 inches format, and includes more than 250 professionally reviewed species accounts and 250 full colour photographs, a comprehensive bibliography, a history of ornithology in Alberta and appendices on migrants, accidentals and common identification problems. The price is $45.00 with an additional $3.00 a copy for shipping. Canadian residents must add 7% GST.

THE FEDERATION OF ALBERTA NATURALISTS

Box 1472, Edmonton, Alberta, Canada T5J 2N5

Recovery of Nationally Endangered Wildlife in Canada

In 1988, the Wildlife Minister's Council of Canada endorsed a new strategy to rescue wildlife species at risk of extinction and to prevent other species from becoming at risk. Called RENEW (the acronym for Recovery of Nationally Endangered Wildlife), the strategy brings together all agencies, organizations, and interested individuals to work as a team for the recovery of wildlife at risk. RENEW focuses on those species or populations of terrestrial mammals, birds, reptiles, and amphibians that have been designated as extirpated, endangered, or threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The RENEW strategy is implemented by a committee of the same name composed of the directors of provincial, territorial, and federal government wildlife agencies plus the heads of the three major national wildlife organizations (Canadian Nature Federation, Canadian Wildlife Federation, and World Wildlife Fund [Canada]). The RENEW committee establishes a "recovery team" of experts for each species to produce a recovery plan which then becomes the basis for a recovery program carried out by the responsible governments in cooperation with universities, businesses, and private citizens.

Publications to date:

Canadian Whooping Crane Recovery Plan December 1987
Anatum Peregrine Falcon Recovery Plan October 1988
RENEW Report Number 3: National Recovery Plan for the Baird's Sparrow April 1993
RENEW Report Number 4: National Recovery Plan for the Roseate Turn June 1993
RENEW Report Number 5: National Recovery Plan for the Greater Prairie Chicken October 1993
RENEW Report Number 6: National Recovery Plan for the Whooping Crane January 1994
RENEW Report Number 7: National Recovery Plan for the Loggerhead Shrike March 1994
RENEW Report Number 8: National Recovery Plan for the Marbled Marbled Murrelet May 1994
RENEW Report Number 9: National Recovery Plan for the Gaspesie Caribou November 1994
RENEW Report Number 10: National Recovery Plan for the Vancouver Island Marmot December 1994
RENEW Report Number 11: National Recovery Plan for the Ferruginous Hawk December 1994

RECOVERY OF NATIONALLY ENDANGERED WILDLIFE

Ottawa, Ontario K1A 0H3

Lake Ontario Waterfront Trail

A 325-kilometre Waterfront Trail stretching across the north shore of Lake Ontario, from Hamilton in the west to Trenton in the east, opened in May 1995 as part of the Waterfront Regeneration Trusts' strategy for regenerating Lake Ontario and its waterfront.

The Lake Ontario Waterfront Trail is the result of over 40 partners working with The Waterfront Regeneration Trust, including the provincial government, local governments, private sector service clubs, community groups, and conservation authorities. It will link as many as 160 natural areas, 136 parks and promenades, 69 marinas and yacht clubs, hundreds of historic places and dozens of fairs, museums, art galleries and festivals in a continuous ribbon along the waterfront of Lake Ontario. It will offer lake access for those interested in walking, biking, birding, boating and/or touring the vast natural and cultural heritage of this region.

The Lake Ontario Waterfront Trail guidebook will be available in the spring of 1995 as will an activity calendar. Already available is the Lake Ontario Waterfront Trail Newsletter, Volume 1, Spring 1995.

EDYE ROME/COLLEEN ZANELLO

Waterfront Regeneration Trust, 207 Queen's Quay West, Suite 580, Box 129, Toronto, Ontario M5J 1A7

The Ohio Cardinal

The Ohio Cardinal is a quarterly publication devoted to the study and appreciation of Ohio's birdlife. It exists to provide a permanent and timely record of the abundance and distribution of birds in Ohio; to help document the occurrence of rare species in the state; to provide information on identification of birds and on birding areas within Ohio. Articles on these topics and other aspects of Ohio ornithology are featured. Bird reports and photographs are welcome from any area in the state. The annual subscription is $15.00 U.S. Volume 17, Number 4, pages 116-148, is dated Summer 1994.

EDWIN C. PIERCE

The Ohio Cardinal, 2338 Harrington Road, Arkon, Ohio 44319

The BWD Skimmer

The BWD Skimmer, published by the Bird Watcher's Digest is now in is third year of publication. The February 1995 8-page issue (Volume 3, Number 1) of this bi-monthly newsletter was researched and written by Erik Blom, edited by Mary Beacom Bowers and Bill Thompson, III, and includes highlights of research appearing in *The Journal of Field Ornithology*, *The Auk*, *Birdscope*, *Wilson Bulletin*, and *Birdlife International* as well as notices of upcoming meetings, symposia, festivals and shows of interest to American birdwatchers, and other news items. Annual subscription is $12.00 U.S.

BILL THOMPSON, III

Editor, Bird Watcher's Digest, P. O. Box 110, Marietta, Ohio 45750

Notice of the 117th Annual Business Meeting of The Ottawa Field-Naturalists' Club

The 117th Annual Business Meeting of The Ottawa FIeld-Naturalists' Club will be held in the auditorium of the Victoria Memorial Museum Building, McLeod and Metcalfe streets, Ottawa on Tuesday 9 January 1996 at 19:30 h.

DAVE SMYTHE

Recording Secretary

Call for Nominations: The Ottawa Field-Naturalists' Club 1996 Council

Candidates for Council may be nominated by any member of The Ottawa Field-Naturalists' Club. Nominations require the signature of the nominator and a statement of willingness to serve in the position for which nominated by the nominee. Some relevant background information on the nominee should be also provided. Deadline for nominations is 15 November 1995.

TRUDY BEDFORD

Chair, Nominating Committee

Call for Nominations: The Ottawa Field-Naturalists' Club 1995 Awards

Nominations are requested from members of The Ottawa Field-Naturalists, Club for the following: Honorary Membership, Member of the Year, George McGee Service Award Citation, Conservation, and the Anne Hanes Natural History Award. Descriptions of these awards appeared in *The Canadian Field-Naturalist* 96(3): 367 (1982). With the exception of nominations for Honorary Member, all nominees must be Club members in good standing. Deadline for nominations is 1 December 1995.

BILL ARTHURS

Chair, Awards Committee

Minutes of the 116th Annual Business Meeting of The Ottawa Field-Naturalists' Club, 10 January 1995

Place and Time:	Auditorium, Canadian Museum of Nature, Metcalfe and McLeod Streets, Ottawa, 19:30 hrs.
Chairperson:	Frank Pope, President,
Attendance:	Thirty-three persons attended the meeting.

Frank Pope opened the meeting by asking members to spend the first half-hour reviewing copies of the minutes of the previous meeting, the Treasurer's report, and the reports of Committees.

1. **Minutes of the Previous Meeting**

No errors or omissions were identified. It was moved by Bill Cody (2nd Ellaine Dickson) that the minutes be accepted.

(Motion Carried)

2. **Business Arising from the Minutes**

Frank Pope announced that a proposal to modify Article 17 of the Constitution had been submitted for publication in *The Canadian Field-Naturalist* and subsequent consideration at the next Annual Business Meeting.

3. **Treasurer's Report**

Treasurer Gillian Marston opened her remarks by noting the favourable report from the Club's Auditor and the overall healthy state of the Club's finances. In reviewing details of the financial statements, she noted an increase in Members Equity from \$191,940 to \$216,097, and the establishment of a reserve fund of \$100,000. She also noted an increase in the de Kiriline Lawrence Conservation Fund from \$6,626 to \$10,478, as a consequence of the Club's policy to transfer the proceeds of the sale of Club items and donations that are not dedicated for a specific purpose, to the fund.

It was moved by Gillian Marston (2nd Ken Young) that the Treasurer's report be accepted.

(Motion Carried)

4. **Committee Reports**

Frank Pope introduced each of the Committee reports and asked for comments and questions from the floor. There was one comment on the report of the Macoun Field Club pointing out that the all-day bus trip mentioned in the first paragraph was arranged by the Macoun Field Club rather than the Excursions and Lectures Committee.

It was moved by Dave Moore (2nd Mike Murphy) that the Committee reports be accepted.

(Motion Carried)

5. **Nomination of the Auditor**

It was moved by Ken Young (2nd Ellaine Dickson) that Janet Gehr continue as Auditor for another year.

(Motion Carried)

6. **Report of the Nominating Committee**

On behalf of the Nominating Committee, Barbara Campbell presented the following slate of candidates for the 1995 Council (new members are indicated with an asterisk):

President	Frank Pope
Vice-President	Michael Murphy
Vice-President	Dave Moore
Recording Secretary	Dave Smythe
Corresponding Secretary	Eileen Evans
Treasurer	Gillian Marston
Other Council Members	
Ron Bedford	Carol German
Fenja Brodo	Christine Hanrahan*
Lee Cairnie	Jeff Harrison
Bill Cody	Cendrine Huemer
Francis Cook	Ann MacKenzie*
Ellaine Dickson	Patricia Narraway
Colin Gaskell	Jane Topping
Trix Geary*	Ken Young

Three members of the 1994 Council, Bill Gummer, Enid Frankton, and Stephen Gawn, chose not to stand for re-election and one member, Jack Rowmanow, resigned during the term of Council.

It was moved by Barbara Campbell (2nd Eileen Evans) that the proposed slate be accepted.

(Motion Carried)

7. **New Business**

Frank Pope reported that he had attended the Governor General's Levee and had thanked the Governor General for being Patron of the Club during his tenure.

Frank Pope thanked the members of the outgoing Council for their support and hard work during 1994.

8. **Presentation by the Education and Publicity Committee**

Dave Moore gave an audio-visual presentation on the members of the Education & Publicity Committee and the results of their work, in which he emphasized new initiatives to publicize the Club. He concluded with special thanks to the members of the Committee.

9. **Adjournment**

At 2100 hrs. it was moved by Lee Cairnie (2nd Ellaine Dickson) that the meeting be adjourned.

(Motion Carried)

DAVE SMYTHE
Recording Secretary

Committee Reports for 1994 to The Ottawa Field-Naturalists' Club

Awards Committee

The following awards were presented at the annual soiree held on April 29, 1994:

1. 1993 Member of the Year: David W. Moore
2. George McGee Service Award: Bill Holland (posthumously)
3. Conservation Award (member): Jacques Cayouette
4. Conservation Award (non-member): Donna Wilson
6. The Anne Hanes Natural History Award: Mary J. Moore
7. President's Prize: awarded by Frank Pope to Eileen Evans.

Citations were published in *Trail & Landscape* and *The Canadian Field-Naturalist*.

ENID FRANKTON

Birds Committee

The Committee maintained the bird status telephone, and prepared an article for *Trail & Landscape* that summarized the reports made to the status line in 1993. The Committee made good progress on the project it started in 1993 to archive some of the Committee's files and records.

The Committee finalized the 1993 Christmas Bird Count results, organized the annual Seedathon and the second annual four-week fall count, and prepared the 1994 Christmas Bird Count. The Committee looked after the Club's bird feeders using seed purchased through the Annual Seedathon.

Efforts were begun to re-establish a computerized database of bird sightings and to re-vitalize the Bird Records Sub-committee. The Committee also initiated efforts for closer liaison with the Conservation Committee.

STEPHEN GAWN

Computer Management Committee

The Committee provided ongoing technical support and technical services to various Club committees and officers during 1994.

Included were:

- assistance in the selection of an accounting software package for the Fletcher Wildlife Garden
- acquisition and installation of a fax/modem facility for the computer used by the Editor of *The Canadian Field-Naturalist*
- maintenance and support of the computers used by the Membership Committee and the Publications Committee

MICHAEL MURPHY

Conservation Committee

The Conservation Committee acted on behalf of the Club on a number of conservation and policy issues.

The Committee is maintaining an ongoing liaison and monitoring program with Conservation Authorities and the Ontario Ministry of Natural Resources with respect to various interests, including watershed studies of Sawmill Creek and the Jock River, as well as ice blasting alternatives for the Rideau River.

Committee members participated in the Marlborough Forest Advisory Committee and the Natural Environment Study for the Regional Municipality of Ottawa-Carleton (RMOC) Official Plan, and are involved in the RMOC Wetlands Working Group.

Various submissions were made to the cities of Aylmer, Ottawa, Nepean, Kanata, and Gloucester and to the Ontario Municipal Board to advocate the protection and enhancement of natural areas in the Ottawa District.

MICHAEL MURPHY

Education and Publicity Committee

The Education and Publicity Committee set up the Club's display at 6 locations, covering 11 days, and using about 50 Club volunteers. The Committee supplied speakers/leaders for 11 presentations.

The Committee distributed advertisments (including bilingual posters) for Club meetings over an ever widening network, including libraries and nature shops. A survey of where membership applications are being picked up was undertaken in conjunction with the Membership Committee.

The Committee supplied judges and prizes for the annual Ottawa Regional Science Fair and a prize for an interdepartmental poster competition sponsored by the National Archives of Canada.

The Committee sold almost $600 worth of Club items at monthly meetings and walks.

The Committee has finished cataloguing its slide collection.

The Committee sent a mailing to science teachers and librarians at local schools to promote *Trail & Landscape* and the Macoun Field Club.

The Committee established the Club as an information provider on the National Capital FreeNet.

DAVID MOORE

Excursions and Lectures Committee

The Committee organized 48 field trips; nearly 80% of these were within the Ottawa District and one was a weekend trip to Algonquin Provincial Park. Non-Committee members organized a 16-day excursion to Newfoundland for the Club.

The Committee also arranged a wide range of evening lectures, all of which were complemented by slide presentations. Attendance at these was higher than the previous year; attributable in part to the efforts of the Education and Publicity Committee.

The Committee arranged three social functions: the Annual Soiree in April, the Members' Slide Night in September, and the New Members Night in November.

COLIN GASKELL

Executive Committee

The Executive Committee met twice.

In January the Executive Committee decided that printed material at the Annual Business Meeting should not be read aloud, and that the 116th Annual Business Meeting should include a slide show on Club activities during 1994. Ideas were exchanged about new programs and activities needing special attention.

In mid-summer the Executive Committee approved two urgent requests for funding. The first was from the Canadian Museum of Nature that needed "stakeholder" funding to initiate publication of a list of rare plants in the Northwest Territories. The second was from the Conservation Committee to bring a witness from Vancouver to testify at the Ontario Municipal Board hearing on the development plan for Carson Woods.

FRANK POPE

Finance Committee

The Finance Committee met three times in 1994. New items considered were policies for maintaining a reserve fund and for making investments. Recurring items included membership fees, insurance, and the annual budget.

KEN YOUNG

Fletcher Wildlife Garden Management Committee

The Backyard Garden is about 90% complete. A team has been formed to perform regular maintenance (such as cutting grass and weeding flower beds).

Interpretative signs have been put up in the Old Woodlot and additional leaves have been obtained and spread. Many areas have benefited from natural succession, especially the sedge meadow.

A new birdfeeder has been set up, with a sign dedicating it to George McGee and Bill Holland. Consumers Gas has made another $5,000 donation; it will be used for interpretative efforts, including signs. Large signs have been erected at the entrance. A self-guided trail brochure has been produced and has been distributed at functions and to people given tours. Ten tours, five of which were advertised to the public, were given in 1994.

Agriculture Canada has been slow in providing the use of Building 138 as the Interpretative Centre.

JEFF HARRISON

Macoun Field Club Committee

The Committee met every two months to organize a range of activities for the members of the Macoun Field Club. During the school year, indoor meetings and field trips alternated weekly. There were several camping trips for the older members. A major trip was an all-day bus trip arranged by the Excursions and Lectures Committee.

Parts of two field trips were videotaped, with the intention of making a video promoting the Macoun Field Club.

The Macoun Field Club published the 48th issue of *The Little Bear* in June.

ROBERT E. LEE

	CANADA		FOREIGN		
Type	Local	Other	USA	Other	Total
Individual	402 (368)	144 (155)	23 (33)	4 (5)	573 (561)
Family	335 (335)	24 (23)	4 (4)	0 (0)	363 (362)
Sustaining	29 (49)	4 (3)	1 (2)	0 (0)	34 (54)
Honorary	14 (15)	10 (9)	1 (1)	0 (0)	25 (25)
Life	15 (15)	18 (18)	3 (4)	2 (2)	33 (39)
Total	795 (782)	200 (208)	32 (44)	6 (7)	1033 (1041)

Membership Committee

In November 1994, membership in the Club stood at 1033. A detailed membership breakdown, with 1993 figures in brackets, is provided in the accompanying table.

Dr. H. M. Raup of Petersham, Massachusetts; Mrs Verna McGiffin of Pakenham, Ontario; Dr. D. B. O. Savile of Ottawa; and Miss Mary E. Stuart of Ottawa, all Honorary members and all members since 1944, were added to the "Golden Anniversary" list.

PATRICIA J. NARRAWAY

Publications Committee

The Committee oversaw the publication of seven issues of *The Canadian Field-Naturalist* (under the editorship of Francis Cook), four issues of *Trail & Landscape* (Fenja Brodo), and three issues of the *Greenline* (Jim Reil).Volume 106, Issue 4; Volume 107 Issues 1 to 4; and Volume 108 Issues 1 and 2 of *The Canadian Field-Naturalist* contained 1016 pages, 62 articles, 68 notes, 15 COSEWIC articles, 110 book reviews, 628 new titles, 4 commemorative tributes, and 42 pages of news and comments. The publishing schedule is almost back to normal. More than 800 copies of *The Canadian Field-Naturalist* were mailed to non-Club-member subscribers; almost half of these were outside Canada. Warren Ballard and Robert Anderson were newly appointed Associate editors. Indices to Volumes 106 and 107 were prepared by Leslie Cody.Volume 28, Issues 1 to 4 of *Trail and Landscape* contained 152 pages, about 15% of which were bird-related.

RONALD E. BEDFORD

The Ottawa Field-Naturalists' Club Financial Statements:
Year ended September 30, 1994

Auditor's Report

To the Members of THE OTTAWA FIELD-NATURALISTS' CLUB:

I have audited the balance sheet of The Ottawa Field-Naturalists' Club as at September 30, 1994, and the statement of operations and members' equity for the year then ended. These financial statements are the responsibility of the organization's management. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, The Ottawa Field-Naturalists' Club derives some of its revenue from memberships and fund-raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the organization.

In my opinion, except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenues referred to in the preceding paragraph, these financial statements present fairly, in all material respects, the financial position of the organization as at September 30, 1994, and the results of its operations for the year then ended in accordance with generally accepted accounting principles.

JANET M. GEHR
Chartered Accountant

North Gower, Ontario
5 January 1995

The Ottawa Field-Naturalists' Club
Balance Sheet
September 30, 1994

	1994	1993
ASSETS		
CURRENT ASSETS		
Cash	260.283	245.502
Accounts Receivable	7.491	12.237
Interest Receivable	3.022	2.860
Prepaid Expenses	1,608	1.595
	272.404	262.194
FIXED (Note 3)		1.255
LAND - Alfred Bog	3.348	3.348
	275.752	266.797
LIABILITIES, FUNDS AND MEMBERS' EQUITY		
CURRENT LIABILITIES		
Accounts Payable	30.327	43.348
Deferred Income	9.871	11,668
	40.198	55.016
FUNDS (Note 4)	12.957	13.341
LIFE MEMBERSHIPS	6,500	6.500
CLUB RESERVES	100.000	100.000
GENERAL EQUITY	116,097	91.940
	275.752	266.797

The Ottawa Field-Naturalists' Club
Statement of Members' Equity
September 30, 1994

	1994	1993
EXCESS INCOME (EXPENDITURES)		
The Ottawa Field-Naturalists' Club	589	5.140
Canadian Field-Naturalist	21.629	-4.420
	22.218	720
OTHER INCOME (ALLOCATIONS)		
Bequest - L. de Kiriline-Lawrence.		6.627
Donations - For wetlands.		200
Donations - Misc. upon membership renewal	3,399	3.112
Allocation to Louise de Kiriline-Lawrence Fund	-1,460	-6.627
Allocations to Alfred Bog		-4.076
	1.939	-764
TOTAL INCOME	24.157	-44
MEMBERS' EQUITY, Beginning of Year	191.940	191.984
MEMBERS' EQUITY, End of Year	216.097	191.940

The Ottawa Field-Naturalists' Club
Statement of Operations - OFNC
Year Ended September 30, 1994

	1994	1993
INCOME		
Membership	14,099	14.288
T&L Subscriptions and Back Issues	645	1.467
Interest	1.864	2.063
Other Sales	1.311	2.290
Special Publications	149	357
Conference (Net)		1.429
Total Income	18.068	21.894
EXPENSES		
OPERATIONS EXPENSES		
Affiliation fees	295	235
Computer	3,955	444
Depreciation	1,255	1.500
Membership	2,564	2.327
Office assistant	750	730
Operations	2,450	2.874
OFNC GST Rebate	-591	-879
Total Operations Expenses	10.678	7.231
CLUB ACTIVITY EXPENSES (Net)		
Awards	8	54
Soiree	356	274
Birds	334	1.976
Conservation	184	30
Education and Publicity	403	283
Excursions and Lectures	-1.703	-1.012
Fletcher Wildlife Garden		200
Macoun Club	1.107	1.030
Trail & Landscape	6,112	6.688
Total Club Activity Expenses	6,801	9.523
	17.479	16.754
INCOME OVER EXPENSES	589	5.140

The Ottawa Field-Naturalists' Club
Statement of Operations - CFN
Year Ended September 30, 1994

	1994	1993
INCOME		
Memberships	9,317	9,525
Subscriptions	19,029	23,196
Sub-Total	28,346	32,721
Reprints	8,848	4,480
Publication charges	34,737	9,454
Back numbers	225	98
Interest and exchange	10,339	11,184
Total Income	82,495	57,937
EXPENSES		
Publishing	37,443	39,619
Reprints	5,956	4,197
Circulation	5,369	9,996
Editing	3,707	901
Office assistant	4,675	4,542
Office supplies	3,736	1,631
Advertising	134	134
Honoraria	3,000	3,000
GST Rebate	-3,154	-1,663
	60,866	62,357
INCOME OVER EXPENSES	21,629	-4,420

The Ottawa Field-Naturalists' Club
Notes To The Financial Statements
September 30, 1994

1. *Authority and Activities*

The Ottawa Field-Naturalists' Club is a non-profit organization incorporated under the laws of Ontario (1884). The Ottawa Field-Naturalists' Club promotes the appreciation, preservation and conservation of Canada's natural heritage; encourages investigation and publishes the results of research in all fields of natural history and diffuses information on these fields as widely as possible. It also supports and cooperates with organizations engaged in preserving, maintaining or restoring environments of high quality living things. Membership is open to any person or family, upon application and payment of dues. Payment of the Annual Dues as set out in the By-laws will be a necessary condition of the continuation of Membership.

2. *Significant Accounting Policies*

Membership, subscriptions and donations are recorded as received. All other revenues and expenditures except for inventory are accounted for on the accrual basis. Memberships are allocated to The Canadian Field-Naturalist publication on a pre-determined percentage.

Supplies, records, tapes and other items held for resale are expensed when purchased.

Fixed assets are recorded at cost and are depreciated on a straight line basis, for assets acquired prior to 1990. Fixed assets acquired after 1989 are expensed.

Life memberships paid since 1977 are recorded at the fee in effect at that time. There are 39 life members.

3. *Fixed Assets*

	1994	1993
Cost	$ 16,748	$ 16,748
Accumulated Depreciation	$ 16,748	15,492
Net Book Value	$ -	$ 1,256

4. *Funds*

	1994	1993
Baldwin Memorial Fund	$ 358	$ 358
Seedathon	888	875
Anne Haines Memorial Fund	815	890
de Kiriline-Lawrence Fund	10,478	6,627
Alfred Bog	418	4,591
	$ 12,957	$ 13,341

Book Reviews

Zoology

An Annotated Checklist to the Birds of Greenland

By David Boertmann. 1994. Meddelelser om Grønland, Bioscience 38:1–63. Kommissionen for videnskabelige Undersøgelser i Grønland. Available from: Geografforlaget, Fruerhøjvej 43, DK-5464 Brenderup, Denmark. DKK170.

This is a welcome, up-to-date, and highly competent review of the status of birds in Greenland, last comprehensively treated by the late Finn Salomonsen in 1967 (*Fuglene på Grønland*; in Danish, a translation into English by R. G. B. Brown having been circulated within Canada in 1982). The author acknowledges the help of some forty correspondents, but has done a great deal of work himself, both in the field and in re-examining museum material in collections in Denmark and in Greenland itself. At a time when the national bird collection in Ottawa apparently has been dismissed by the President of the Canadian Museum of Nature as an anachronism of no interest to the public and of minor scientific value, as judged by the elimination of research in ornithology, it is good to be reminded that collections of bird skins continue to be important in several ways. When properly looked after, they provide permanent records of what was where, and when. As Boertmann illustrates, the identification of some early specimens has recently been revised in the light of new knowledge. Well-prepared skins are also sources of information in ways that could not have been foreseen by the collectors. Such modern techniques as DNA analysis, which make it possible to learn from tiny fragments of tissues a great deal about the affinities of species and populations, have made museum collections more valuable to scientists than ever before. Boertmann also emphasizes the educational value of the growing number of small local collections in the settlements in west Greenland. How well does northern Canada compare in this respect?

Greenland is our nearest neighbour to the east, so that it shares with the Canadian Arctic nearly all the 58 well-established breeding species and some of the 17 regular visitors to Greenland listed here. The visitors include proportionately more from the Palearctic than are reported from the eastern Canadian Arctic, perhaps due in part to a greater awareness of European birds among the people of Greenland. From the conservation point of view, Greenland and Canada share responsibility for many large stocks of seabirds, in winter as well as in summer. There is, as yet, no formal joint commitment to do so. This is particularly necessary for the Thick-billed Murre (Brunnich's Guillemot) *Uria lomvia*, heavily hunted in both countries with resulting great reductions in numbers at some formerly large colonies in west Greenland. There are still millions of these birds, which is just as well as the combined kill in the two countries is of the order of 1-1.5 million from a species that takes many years to reach sexual maturity, and has a clutch-size of one.

Encouragingly, many of the changes of status reported here reflect increases, not decreases, though Barrow's Goldeneye seems to have ceased to breed. Snow and Canada geese have increased greatly, the latter bringing with them all the taxonomic chaos that exists among the stocks in eastern Canada. It remains something of a puzzle that the variety of breeding shorebirds in west Greenland is even smaller than in the High Arctic.

The hope must be that this new list will encourage the preparation of a companion, covering the eastern Canadian Arctic, where much has been found since Godfrey compiled *The Birds of Canada*. There have been several valuable local lists, but no broad review, except the discussion of the birds of the High Arctic Islands by Ouellet in 1989.

Hugh Boyd

1032 Pinewood Crescent, Ottawa, Ontario K2B 5Y5

British Birds in 1989-1990: The Conservation and Monitoring Review

By D. A. Stroud and D. Glue. 1991. British Trust for Ornithology/Nature Conservancy Council, Thetford, England. 216 pp., illus. £6.95.

This review is a working document which I read with a mixture of alarm, envy, and hope. Printed on economical paper, it packs a lot of information into its 216 pages. It is divided into four parts. The first part deals with 16 major conservation issues; the second with reports on 31 studies having a special focus. The third part is a series of brief status reports on 167 breeding species which are subject to regular monitoring. A short but critical conclusion, summarising a not entirely promising picture, shows there is much work to be done. Each report is short, and on occasion cryptic, which allows the editors to include a large number of inputs.

The review shows that, despite a very dedicated effort by a large group of contributors, there is so much more work to do. Real progress has been slow despite the increased awareness of environmental issues. Conclusions like "poor management of fish stocks ... reduces marine resources for man" sound all too familiar. I certainly envy Britain's large network of groups, clubs, and individuals who give freely of their time for conservation. The results show what can be done and give hope that we will achieve true progress.

ROY JOHN

Uranium Saskatchewan Association Inc. 600 Spadina Crescent East, Saskatoon, Saskatchewan S7K 3G4

Fish Watching: An Outdoor Guide to Freshwater Fishes

By C. Lavett Smith. 1994. Cornell University Press, Ithaca. x + 216 pp., illus. + plates. Cloth U.S. $42.50; paper U.S. $19.95.

The avowed purpose of this book is to promote fish-watching as a worthwhile activity for the naturalist. Whether the author succeeds in doing so will depend on the personality of the reader. In my opinion, people who came to love nature through bird-watching and extensive hiking will not find fish-watching very gratifying. Fish are prey for many animals, so they try hard not to be seen or heard. After reading this book, I am left with the feeling that fish-watching is for the quiet naturalist who likes to take it easy, sitting by the water or slowly paddling along the shoreline, wondering about the life of interesting but rather secretive animals.

The book is divided into four sections. In the first one, general advice on fish-watching is given. Polaroid sunglasses (to cut glare from the water's surface), a field notebook, good boots, and patience appear to be the fish-watcher's main tools of the trade (I would have added bug repellent, the fish-watcher being, obviously, always near water). The author also gives tips on how to find the best vantage points (high is the key), how to take notes (right away), and how to photograph fish (but don't expect a long exposition of professional methods here). The second section is "watching by habitat", in which descriptions of aquatic ecosystems (e.g., rocky or marshy creeks, rivers, estuaries, ponds, lakes, wetlands) are given along with a list of the 10 or so species most likely to be found in them. The third section contains accounts of the 32 most important North American families of fish (the author correctly points out that species accounts are not necessary, as most fish cannot be identified down to the species level just by sighting them in the water). Most families receive a one-page treatment on their general appearance, habitat, and the behaviour one is most likely to witness if the fish is spotted. Some comments on distribution are given, but they are scanty and maps would have been a lot more useful. The final section, on the general biology of fishes, is insightful in most places but too short in a few others. The uninitiated naturalist will be intrigued by the mentions of "catch per unit effort" or "capture-recapture", but will pine for examples to illustrate these methods of estimating population size. Also, I would have liked more information on physiological ecology (e.g., the various ways in which fish react to low oxygen availability) and behavioural ecology (e.g., why do fish school?) but I admit that this is a matter of personal taste.

The book is written in an engaging way by a scientist (Emeritus Curator of the Department of Herpetology and Ichthyology at the American Museum of Natural History) who has a healthy curiosity about nature. Many examples are given of questions that one can ask after seeing fish in particular circumstances. The author did not convince me, however, that answers to these questions are attainable by mere observation, without actually catching the fish and extensively sampling its habitat. But the experience of simply observing a fish may be enough to prompt one to read more about these animals and bring a renewed commitment to preserving their habitat which, as we all know, is still vulnerable to abuse and encroachment by human activities.

STÉPHAN REEBS

Département de Biologie, Université de Moncton, Moncton, New Brunswick E1A 3E9

Environmental Physiology of the Amphibians

Edited by Martin E. Feder and Warren W. Burggren. 1992. University of Chicago Press, Chicago. 646 pp., illus. Cloth U.S. $135; paper U.S. $47.50.

The "amphibian" has long been the experimental animal of choice for physiologists. In the past, experimental results from a single amphibian species were frequently portrayed as being representative of an entire order (i.e., the physiological responses of the Leopard Frog, *Rana pipiens*, would be accepted as characteristic of all other species of frogs). The effort of Feder and Burggren in *Environmental Physiology of the Amphibia* to correct this tendency toward broad generalizations is commendable. The common theme throughout the book is the diversity of physiological responses of "amphibians". The authors of each chapter have further emphasized that members of each order (frogs, salamanders, and caecilians) have their own level of physiological diversity.

The book provides a broad, comprehensive review of available information on the physiology of amphibians. The editors intend to provide a bridge between studies of physiology conducted in a laboratory setting with the animals' expected responses in their natural environment. When possible, they have included information from field studies, as well as instructions on how to simulate natural conditions. Both comparative and contrasting data occur in numerous tables and summaries found throughout the book. The editors have succeeded in providing a compilation of information from forty authors, writing on topics that range from the physiological aspects of behavior to the mathematical properties and biophysics of heat and mass transfer. The result is a readable, interesting book that is a valuable data resource for anyone with an interest in amphibians.

The sixteen chapters are organized under four main topics: (1) control system (neural and endocrine systems); (2) exchange of gases, osmolytes, water, and heat; (3) energetics and locomotion; and, (4) development and reproduction. None of these areas is exclusive of the others, although the editors have minimized overlap and redundancy. Each topic area has an introductory section that places the subject matter in a historical and a current context. In each chapter, the authors have also provided a short introduction that involves a discussion of pertinent terminology and background information that will allow the reader to understand the relevance of the material and place it in a natural context. Although each section is readable and understandable to a general audience, the depth of coverage of each topic may be greater than that of the interest of the casual reader. Individuals interested in amphibian husbandry would have better luck consulting other resources because of the book's specificity. However, this book provides scientific explanations for an endless number of physiological phenomena such as color change, underwater respiration, aggregation and migration behavior, cannibalistic tadpoles, hypersaline-adapted amphibians, call recognition, molting, to mention only a few.

In each chapter, there is a section suggesting areas of future study. This book is recommended reading for students considering research in amphibian physiology. It provides a wealth of possible research topics. The extensive bibliography (95 pages) will make this a valuable resource for anyone interested in this line of study. Citations in the bibliography include those listed in the chapters, as well as additional references the editors felt should be present. In the back are two indices (systematic and subject) that are up-to-date and are sure to expedite any keyword search.

Although our overall impression of the volume is positive, it suffers from one major limitation. The unifying principle of biology is evolution, and yet there is not a single application of phylogenetic methodology to the explanation of trends and direction of change in physiological evolution. The extensive bibliography misses such seminal works as Hennig, Wiley, and Brooks and McLennan. At a minimum, one would have expected at least a cursory application of phylogentic methods to data where a suitable phylogenetic hypothesis exists, and even predictions made about the physiological status of taxa where data are wanting. The editors could have taken the lead in providing such an evaluation, even in a chapter summarizing new directions for comparative physiological research. Consequently, this volume falls far short of being exemplary of how comparative physiology ought to be approached nowadays. Notwithstanding, we hope that *Environmental Physiology of the Amphibians* will stimulate and facilitate further work on wider range of amphibian taxa, and facilitate evolutionary approaches to the study of physiology.

AMY LATHROP AND ROBERT W. MURPHY

Department of Ichthyology and Herpetology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6

Wild Cats of the World

By David Alderton. 1992. Facts on File, New York, New York. 192 pp., illus. U.S. $25.95; Cdn. $32.95.

Wild Cats of the World is one of at least fifteen books in the recent *Facts on File* series. Each summarizes currently available information on a particular group of animals. Although no specific objective for writing the book was presented, Alderton provides a general overview of the wild cats, emphasizing their status and conservation.

The first chapter discusses the relationships between cats and people. Specific sections include hunting and commercial trade, predation on humans, and captive breeding. The second chapter provides a comparative approach to felid morphology and physiology. The third chapter is entitled "Reproduction" and includes sections on courtship and communication, mating, gestation, birth, and development of young. This chapter may have more appropriately been labelled "Reproduction and Mortality" as it also contains a section on various forms of mortality. The fourth chapter outlines felid evolution and distribution.

The fifth and final chapter provides accounts of 39 felid species, including the Onza and Iriomote Cat, which remain under taxonomic scrutiny. Species accounts ranged from about one to seven pages in length. Each account provides general a description of the species' external morphology and natural history as well as a range map. Some physical descriptions could have been more comprehensive. For example, the Spanish Lynx was stated as being "similar in general appearance to the Eurasian lynx" but there was only a partial sentence devoted to describing the appearance of the Eurasian lynx, along with a photograph including only the head and front shoulders. Also, readily available information such as weights of Bobcats were not reported. To my disappointment, photographs were used in only 24 of the species accounts. Although I recognize the difficulty in obtaining photographs of some species of cats, it would have been advantageous to solicit photographs from additional sources to better describe physically some of the other cat species. There was obvious disparity in species' representation, with the European Wild Cat receiving seven pages of treatment while the Bobcat received less than two pages. Concluding the book is a checklist of species, a list of additional books pertaining specifically to or relevant to cats and, an index.

With wild cats receiving so much attention in recent years, particularly in response to conservation biology and trade in skins, I remain amazed at the lack of information available for more than half of the recognized species. Alderton effectively brings this important point into focus, as well as the urgent need to obtain adequate data on distribution and population sizes for many of the species to enhance current management for their preservation.

Overall, I believe Alderton provides a solid introduction to this highly specialized group of carnivores. Although this book contains information valuable to scientist and layperson alike, it is most suited to those desiring a general overview of the wild cats.

JERROLD L. BELANT

Fond du Lac Ceded Territory Conservation Department, 105 University Road, Cloquet, Minnesota 55720

Present address: United States Department of Agriculture, Denver Wildlife Research Center, 6100 Columbus Avenue, Sandusky, Ohio 44870

Lizard Ecology: Historical and Experimental Perspectives

Edited by L. J. Vitt and E. R. Pianka. 1994. Princeton University Press, Princeton, N.J. xii + 403 pp. U.S. $45.

Finally, phylogenetic theory has made a significant entry into ecology beyond the theoretical framework. When I first heard of this volume, I was very skeptical about the contents as a predecessor, also co-edited by Vitt, offered little in way of evolutionary interpretation and methods (J. W. Wright and L. J. Vitt. *Editors*. 1993. *Biology of Whiptail Lizards (genus Cnemidophorus)*, Oklahoma Museum of Natural History). However, this volume marks a significant departure from the typical story-telling dogma and/or presenting of interesting, but uninterpretable facts that has permeated the comparative ecological literature for decades.

The 14 chapters in this volume are divided into four major sections, including (1) reproductive ecology, (2) behavioral ecology, (3) evolutionary ecology, and (4) population and community ecology, the first two sections having four chapters each, and the latter three. The chapters are authored mostly by third generation lizard ecologists, perhaps accounting, in part, for the large phylogenetic content of the various chapters. However, in some cases there is still much to be learned about phylogenetic theory. For example, Niewiarowski discusses how one might understand geographic life-history variation in lizards within a phylogenetic framework. However, continuous populations should have no recoverable phylogeny because of reticulation; i.e., gene flow. If a clear phylogeny can be demonstrated, then it is

arguable that one is actually examining a single species.

Despite such naiveity about phylogenetic theory, the book does make significant progress in comparative biology. The text has been well edited and the material is quite readable with numerous figures, charts, and phylogenetic trees. It is a state-of-the-art summary of both knowledge and approaches to understanding lizard ecology. However, to gain an appreciation for what many of the chapters are saying, a sound knowledge of phylogenetic theory is required. This book is not necessarily well suited for bedside reading by the merely curious. And it will not make a good coffee table book as there are no high-gloss photographs. Rather, this is a volume of the highest academic acumen. It is the standard for other such summaries to follow.

ROBERT W. MURPHY

Department of Ichthyology and Herpetology, Royal Ontario Museum, 100 Queen's Park, Toronto M5S 2C6

Guide to Marine Mammals of Alaska

By Kate Wynne. 1992. Alaskan Sea Grant College Program, University of Alaska, Fairbanks, Alaska. 75 pp., illus. U.S. $15.95.

This book is designed for the cockpit of a boat or the dash of a car. And very well designed it is too. It is spiral bound so the pages lay flat. It opens out to just larger than a standard 8 x 11 inch format. The paper is thick, flexible, and coated in plastic, meaning the book will be weather resistant.

A well-thought-out introductory section is followed by the species accounts. These latter are divided into three colour-coded sections; cetaceans, pinnipeds, and fissipeds. Each pair of pages covers one species. The top page has a large illustration bordered by basic information on the species depicted. The second page has colour-coded insets showing the above-surface silhouette. Where appropriate, a differently coloured inset shows comparable silhouettes of similar species. There are one or two additional small photographs and a summer-winter range map. The text is given in note form, with the most useful characteristics presented in bold text.

With a little practice, using the colour-coded page edges, it is easy to flip the book open at about the right page. The format given above is easy to use in the field, even in a pitching boat. This is important when observing mammals that are only partially visible for brief periods. Only short, intermittent glances away from the ocean would be necessary to look up the key information, thus maximising an observer's field observation time. While most of the book is illustrated by photographs, ten of the whales are depicted by an artist. The artists renditions are somewhat more boldly patterned than I have observed in the field. In particular the Fin and Minke whales are significantly more white and I wondered if this was an Alaskan peculiarity. If this is the case I can find no mention of regional colour patterns in other texts. Also the Humpback photograph shows a black finned individual. All those I have seen have had largely white fins and I assume the whale shown is an abnormally-coloured individual. In which case it would be better to use a more typical individual as an illustration.

The book covers the 17 species of whale, 10 species of seals and sea lions and the two fissipeds (Polar Bear and Sea Otter) that regularly occur in Alaskan waters. There are a number of other books on sea mammals that contain much more information than this guide. These are also worth buying, but should be used back in port. This is the book to use at sea or along the rain-swept coast.

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ENVIRONMENT

Atlas of Wild Places: In Search of the Earth's Last Wildernesses

By Rober Few. 1994. Facts on File, New York, NY, 240 pp., illus., C$44.95.

The *Wild Places* of the title are defined as areas of the earth which have not been "disturbed by those humans who venture into them", and there are more of them than expected, or perhaps fewer than there should be. Forty-one areas are described and the text for each occupies about two pages. With such a subject, the author and the editor must have had to make difficult decisions about what to exclude from the main body of the book yet keep it viable. The areas are fairly equally distributed among the seven regions of the world, and others were probably investigated initially since the Gazetteer at the end briefly describes another 90 wildernesses.

Not surprisingly, most of the areas contain some of the best birdwatching regions in the world, but this book is directed at readers who need or want an overall description of a region, and geology, climate, plants, animals, and topography are described superficially. Occasionally local tribal people are also mentioned. The photographs are splendid. It is interesting that the book was written, edited, and designed in London, published in the U.S., and printed in Spain, and it is high quality printing.

The text is overwhelmed with superlatives — so many nouns are quantified (highest, largest, biggest, widest, unique, spectacular) it tends to be wearying, and results in a loss of impact.

Some of the areas chosen are well known, such as Royal Chitwan National Park in Nepal and Lake Baikal in Russia. Other areas are not as well known, including the Poor Knights Islands, which even a native New Zealander could not place. Lapland, fairly well populated for a "wilderness" area, counts eight seasons and we might well adopt them. They are springwinter, spring, springsummer, summer, autumnsummer, autumn, autumnwinter, and winter. They could be useful for Canadians to describe a season when there is a blizzard in the third week of April or +12°C in November.

This is a good reference book for a well-heeled, jaded traveller looking for new, exotic destinations, and a good one for browsing.

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Freshwater Marshes

By Milton W. Weller. 1994. University of Minnesota Press, Minneapolis. 154 pp. Cloth U.S. $34.95; paper U.S. $16.95.

Milton Weller has produced a useful introductory book on freshwater marshes of the United States. The book starts well with a good introduction and then goes on to provide a clear account of marsh structure and function. The primary focus of the book is on the prairie potholes in the U.S. and one is struck by the lack of reference to Canadian marshes. The book also mentions in several places U.S. regulations relevant to wetlands such as 404 Permitting but without explanation; this is not useful to general Canadian readers.

There are several minor errors through the text which appear to have resulted from poor editing such as a reference on page 25 to muskrats as detritivores, or conceptual errors on page 26 which indicate that "terrestrial herbivores readapted to the marsh" which, of course, implies that they were originally aquatic species, became terrestrial, and have more recently become semi-aquatic. Also there are misinterpretations of other work such as suggesting that Schindler 1974 attributed his experimental manipulation of lakes with nutrients as being caused by upslope runoff. Also, while the book is generally objective in its treatment of marshes, there are resource-biased generalizations, such as on page 34 where he refers to predation on waterfowl as "being plagued by predators such as striped skunks"; one normally expects predators to increase where prey increase. There are other places where a critical edit of the book would have eliminated these minor errors. Also there are odd changes of grammar moving from third person to first person and back which are awkward.

The chapter on management and restoration of wetlands is good, clear, and well written and shows up some of the other chapters which have not been brought up-to-date. While a few new references have been added to this edition, there is still a preponderance of references to early papers and the recent literature on management and restoration of wetlands has been only lightly used. It is unfortunate that Weller did not care to expand the book into a more continental and ecological approach to marshes. Information about the wetlands of Canada and Mexico would surely complement his accounts of the U.S. marshes and provide readers with a better ecological viewpoint of the importance of marshes in North America.

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Trace Gas Exchange in a Global Perspective

Edited by D. S. Ojima and B. H. Svensson. 1992. Ecological Bulletins 423, Munksgaard International Booksellers and Publishers, Copenhagen, 206 pp., illus. DKK 250.

The materials within this publication are based on presentations and discussions held at the 1990 Sigtuna workshop. The workshop was organized by the SCOPE Project On Trace Gas Exchange and the IGBP Coordinating Panel on Terrestial Biosphere-Atmospheric Chemistry Interactions. The intent of the workshop was to facilitate the linkage of the research being planned by IGAC and the recommendations from the Dahlem Conference on the Exchange of Trace Gases Between Terrestial Ecosystems and the Atmosphere.

The papers were organized into five sections: (1) papers of general relevance, (2) high-latitude, (3) mid-latitude, (4) tropical geographical regions, and (5) rice paddy agriculture. The papers dealt with methods of quantifying the anthropogenic modification of trace gas exchange. There was also an emphasis on specific areas requiring further research. Sections two to five concluded with a report outlining specific research goals, methodology, and timetables for goal attainment.

The publication tends to be technical in nature, aimed at a readership with some background knowledge. The individual papers were well written, with only a few typos. I did have some difficulty in reading some of the figures. Those that were difficult to read were too small for the amount of detail they tried to provide.

The editors have provided a well-organized and readable publication. The book provides a description of ongoing research efforts, techniques in use, and areas for further research. As a result, the book should be of value to individuals undertaking this type of research or having an interest in this field of study.

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Restoration Planning for the Rivers of the Mississippi River Ecosystem

Edited by L. W. Hesse, C. B. Stalnaker, N. G. Benson, and J. R. Zuboy. 1994. Proceedings of a Symposium, 13–15 September 1992. Biological Report 19: 1–502. U.S. Department of the Interior, National Biological Survey, Washington. 502 pp., illus.

This weighty contribution to the "grey literature" of ecological conservation is admirable, depressing, and yet encouraging. Admirable, because it is full of useful information and insights concerning 19 different large river systems in the Mississippi River Basin, well edited and clearly presented. Depressing, because, as the Introduction, by S. Moberly and W. Sheets, and the Epilogue, by L. W. Hesse, make abundantly clear, the fate of these systems is in the hands of politicians and lawyers, neither class well acquainted with, nor seriously interested in, the extremely complex ecological facts of life presented by the sixty or so professionals who wrote the thirty papers printed here.

Encouraging, because some of these professionals see very clearly that their job is not done when they have talked to each other. They have to "reach out" to the public, whether "interested" or not, and they have to learn enough about surviving the legal procedures in which water management is so heavily enmeshed to be able to carry their most important messages through those murky and turbulent chambers to reach the decision-makers before the decisions are made.

Canadians are still, fortunately, less addicted to litigation than Americans. But our problems are serious enough. "Generally, we have used our rivers in North America for just about everything one could think to haul up, float down, pump out, and dump in. Our coastal waters receive billions of cubic meters of municipal effluent and millions of cubic meters of industrial wastewater each year. The quality of most of this water does not meet current water standards for use by humans and wildlife." "Governments do not set out to destroy riverine values, and water development projects have provided such benefits as flood control, navigation, irrigation, and power production. But in the development process, the ecosystems have been damaged, and values have been lost. Rivers suffer from the cumulative effects of thousands of small, and some not so small, abuses. It is essential to adopt an approach that balances habitat conservation with water resources development." "Much of the problem with the way we have treated rivers has to do with the way our institutions and governments are organized. If one wished to condemn rivers to a long, slow, and sure death, the present governmental process was seemingly designed to achieve that end." (Moberly and Sheets, pp. 1-2). There follows an appalling catalogue of the numbers of parties officially involved, in the Mississippi River basin alone: 28 States, numerous Indian tribes, and the Federal Government, which divides its responsibilities between 37 agencies within 9 executive-level departments, and is organized by constituent group (recreational, commercial, aquaculture) and salinity (freshwater vs. marine), so that there is as much intra- as inter-agency warfare. The convenient-seeming habit of using the middles of

rivers as boundaries between jurisdictions adds enormously to the difficulties of behaving rationally in making water resource decisions.

Do we in Canada do any better? We have fewer people, and more water. But, even after the latest bout of "downsizing" in government, unified agencies with coherent, and sustainable, objectives will be hard to find; and there are, undoubtedly, many conflicting interests at stake. Yet, tempting though it must be, ecologists must not despair of the complexity of the world, and their minor additions to it. "Think globally, act locally" has become a watchword, though not an easy one to live up to. Each of us must do what she/he can, whenever and wherever the need arises. Would you care to become involved in the future management of the Ottawa River? Good luck!

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Biotic Diversity in Agroecosystems

Edited by M. G. Paoletti and D. Pimental. 1992. Elsevier Science Publishers, Amsterdam. 356 pp. Dfl 210; U.S. $120.

Diversity continues to be a topic of great concern to growing numbers of people. One aspect, biotic diversity, has become a method of assessing the health of ecosystems. The editors, M. G. Paoletti and D. Pimental, have selected twenty-two papers from a symposium on Agroecology and Conservation Issues in Tropical and Temperate Regions held at the University of Padova, Padova, Italy, on 26-29 September 1990 concerned with biotic diversity in agroecosystems. Agroecosystems, which are often thought to have low biotic diversity, are examined for their contributions to biotic diversity and their interactions with surrounding natural areas.

More than fifty per cent of the papers dealt with the often overlooked and under-researched soil fauna. The rest of the papers covered such varied topics such as a historical look at the uses of forage legumes and cultural sustainability, alternative crops and sustainability, increased diversity in cultivated lands, and colonization of natural areas. A recurring theme in most of the papers was the need for further research, the importance of natural areas surrounding cultivated land, and the large degree of biotic diversity located within the surrounding agricultural lands.

All the papers were technical in nature and relied on original research to provide a number of interesting details. The authors were geographically diverse. They all utilized the standard scientific paper publication format.

All the papers were highly readable and contained, as stated previously, a great deal of detail. The value of the book will be the detail provided in this area of research and the suggestions for additional research. The book will be of interest to individuals with some technical training and interest in the areas of biotic diversity, and agroecosystems.

M. P. SCHELLENBERG

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Tatshenshini: River Wild

Edited by Ken Budd and Rick Careless. 1993. Raincoast Books, Vancouver, 128 pp., illus. Cloth $39.95, paper $29.95.

This volume was assembled as part of the argument to preserve an absolutely fascinating region in northwestern British Columbia for the future. In June 1993, the Government of British Columbia permanently protected the Tatshenshini-Alsek region, an area of almost one million hectors as a Class A provincial park and nominated it as a World Heritage Site. It is bounded on the west and south by Wrangell St. Elias Park, Glacier Bay National Park, and Chilkat Eagle Preserve in the northern Alaska Panhandle and on the north by Kluane National Park in southwestern Yukon Territory.

Seventeen presentations by eminent individuals, surrounded by over 100 absolutely beautiful colour photographs of the wild mountains, rivers, glaciers, plants, birds, and animals are included. These are "A test of Good People" by John Fraser, Speaker of the House, Government of Canada; "A Most Magnificent River" by Rick Careless, executive director, Tatshenshini Wild in Canada and chairman, Tatshenshini International network; "Big Rivers, Big People" by Bart Robinson, editor of *Equinox: The Magazine of Canadian Discovery*; "More Precious than Gold" by Harvey Locke, President, Canadian Parks and Wilderness Society; "A Personal Journey" by Ed Wayburn, Vice President, Sierra Club of the United States; "A Geography of Spirit" by Sally Ranney, President, American Wildlands; "Spirit of the Bear" by Anne Holcroft, biologist and Stephen Herrero, authority on bear ecology; "Nature's Garden" by Heather Hamilton, Conservation Director, Sierra Club of Canada; "A Spectacle of Eagles" by Peter Enticknap, Vice Chairman,

Tatshenshini International; "A Biodiversity of Keystone" by Monte Hummel, President, World Wildlife Canada; "Paddling Turnback" by Ken Madsen, writer, photographer, outdoor educator and kayaker; "Peak Experience" by Pat Morrow, writer, photographer, filmmaker and mountaineer; "A Fairweather View" by Michael Down, mountaineer; "The Wildest River" by Tom Cassidy, General Counsel for American Rivers; "Something about a River" by Brock Evans, Vice President, National Issues, National Audubon Society; and "An Essential Beauty", by Pierre Trudeau, former Prime Minister of Canada.

These individuals, each in their own way, describe the various aspects that make the land so important to preserve for the future: The tall rugged mountains, glaciers, bears, Dall Sheep, Bald and Golden eagles, Peregrine and Gyrfalcons, and beautiful plants found along the river shores and in alpine habitats, to mention only a few. This now protected region will not be visited by most of us, but *Tatshenshini River Wild* will give many the opportunity to view its beauty and learn something about its importance to our world.

WILLIAM J. CODY

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Algonquin Park: Excursions with a Photographer

By Dave Taylor. 1994. Natural Heritage/Natural History Inc., Toronto. 208 pp., illus. $19.95.

Algonquin Park: Excursions with a Photographer is actually three books in one. It is a photo album of Algonquin Provincial Park in Ontario, it is a primer on the ecology of the park, and it is a guide to nature photography. Unfortunately it does not do justice to any of these topics.

While the book does have a few spectacular shots most of them are quite mediocre. In addition, most of the photos are in black-and-white, many are quite small, and the contrast in some is so poor that black is the dominant tone.

As a nature primer the book covers a variety of subjects, from geology to botany to zoology, all superficially. For example, what book on Algonquin would be complete without a section on loons? While we are told loons are a very early form of bird the author does not even mention that loons have solid bones.

As the author is supposed to be a professional photographer it would be hoped that his comments on nature photography would be most valuable. His advice tends to be either quite rudimentary (explaining the gray scale, lens suitability) or somewhat vague (be patient, frame your shot carefully). To be fair he does offer some suggestions on stalking and conveying the difficulty of getting the perfect shot.

The book also suffers from a number of other problems. It lacks even a basic map. The text is also somewhat disorganized. In one chapter alone, as the text flits from one topic to another, he states on five separate occasions that the current topic will be covered more thoroughly in a later chapter. There are also some outright contradictions. On the very page (97) that he states he chose not to include shots of animals in captivity there is a photo of a wolf with a caption that clearly states it was taken in the zoo.

While this is certainly not the definitive book on Algonquin Park or nature photography, it might make a good gift for teenagers who have just developed an interest in photography. If nothing else it will convince them that they can take photos just as good as these.

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MISCELLANEOUS

Dean of Birdwaters: A Biography of Ludlow Griscom

By William E. Davis, Jr. 1994. Smithsonian Institution Press, Washington and London. xiii+234 pp., illus.

Ludlow Griscom (1890-1959) was a well-known American ornithologist and conservationist. A pioneer of the field identification of birds, in the 1920s he became an idol to a group of young birdwatchers, including Roger Tory Peterson and Joseph J. Hickey, Jr. But was he the "Dean of birdwatchers"? In his carefully researched biography of Griscom, the author sets out to answer this question.

The book is divided into five sections. Part one, "The Early Years", details Griscom's background, his studies, career choice, and private life. Griscom was born into a privileged but eccentric family. Birdwatching provided a "satisfying outlet for his energy" (p. 7) during his lonely childhood and by his late teens he was determined to pursue a career in ornithology. He joined the Linnaean Society and the

American Ornithologists' Union, did an A.B. degree at Columbia University and, in 1914, became Arthur A. Allen's first graduate student in ornithology at Cornell University (M.A. 1915). For reasons that are unclear he did not complete a doctorate. Instead, he accepted a position at the American Museum of Natural History (AMNH).

Part two, "Ornithology," follows Griscom's career from the AMNH to the Museum of Comparative Zoology at Harvard where he was Research Curator of Zoology (1927-1948) and Research Ornithologist (1948-1955). This, the longest section in the book, deals with Griscom's work at the two museums, his participation in a number of expeditions, his involvement with the American Ornithologists' Union and the Nuttall Ornithological Club and in what was to become the Boston Museum of Science.

Part three, "In the Field", traces Griscom's activities as a field ornithologist in three chapters: "From Shotguns to Binoculars," "Birdwatching with Griscom," and "Sight Records and Collecting." Part four, "Conservation", details Griscom's involvement with the National Audubon and Massachusetts Audubon societies. Part five, aptly named "The Final Years," takes the reader through Griscom's last years "marred by ill health" (p. 181) until his death in 1959.

The author obviously likes his subject, though he does not cover up Griscom's shortcomings. Thus the person who emerges is a strong-minded, sometimes lovable, at other times less-than-likable human being who, in spite of his many good qualities, was obviously classist, anti-semitic, and racist. This so-called "Dean of Birdwatchers" was also ambivalent about the relative merits of birdwatching in the field, scientific collecting, and laboratory-based ornithology. The writing is good when it is the author's own. Davis' style is lively and interesting. Unfortunately, most chapters contain very long quoted passages from letters, field journals, and reports. These "fillers" mar the book. Shorter quotes, supporting Davis' arguments, would have created a better balance. In my opinion, the editorial policy that allowed the proliferation of so many long quotes to follow each other with only brief connecting texts did no justice to the author, the reader, or the subject of this biography.

Nevertheless, this well-documented and illustrated biography will appeal to a range of readers, including ornithologists along the professional-amateur continuum, field naturalists, conservationists, and biologists.

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A Naturalist in Florida: A Celebration of Eden

By Archie Carr. 1994. Yale University Press, New Haven. 264 + xviii pp. U.S. $28.50.

The lasting contributions of Archie Carr as a herpetologist, nature writer, and conservationist are all highlighted in this collection of articles edited by his wife and prefaced by E. O. Wilson who shares similar roots and joys in nature and writing. Varying in length and source, the articles blend local anecdotes, scientific analysis, and social history and criticism. There are didactic items on habitats and taxonomic groups, accounts of hunting adventures, empathic celebrations of the majesty of nature, and exhortations for necessary stewardship of the environment. Florida is described through its limestone karst, springs, and rivers; herpetofauna including alligators, box turtles, lizards, and cottonmouths; and other dominant or fascinating organisms such as sturgeon, moss, and water hyacinths. Distinctive terms such as *cut-bait fishing* (achieved with dynamite), *hammock* (a particular forest community), and *jubilee* (a mass stranding of marine animals) are described. The biology and mythology of carnivorous plants are excellently presented; the consideration of new arrivals such as armadillos and cattle egrets is superb; the assessment of critical environmental issues such as water systems and loss of species is all the more effective by being low-keyed; and the highly amusing "*A Subjective Key to the Fishes* ..." is a gem. A section of photographs, maps, notes, and index are usefully included.

The volume is a fine contribution to the literature of natural history, both generally and in the specific lineage from William Bartram (often quoted by Carr) through Thomas Barbour and Raymond Ditmars. Carr could be speaking of himself when he describes (p. 109) Bartram as "a sound naturalist, a warm humanist, the father of American conservation, and an able stylist in the romantic prose of his day": for example (p. 165) "A big old live oak without its moss looks like a bishop in his underwear".

Appropriately the styles of the articles differ, reflecting vivid sensitivity to natural richness, gentle humour, and effective awareness, with occasional outrage, of environmental loss. Taken together the articles are educational, entertaining, and insightful, and a reader enjoying them naturally wants to know more of the author. Hence a significant lack of the book is even a brief account of Carr's life: let us hope that someone will soon fill this biographical lacuna.

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Shadowbirds: A Quest for Rails

By William Burt. 1994. Lyons & Burford, Publishers, 172 pp. U.S. $25.00.

This book is about William Burt's quest for photographs of two birds, the Black Rail and the Yellow Rail: "two shadowy little birds of the dark that live in marshes and are very, very difficult to find — and even harder to photograph." The author's absorbing and resonant account of his many years spent in pursuit of these extremely nocturnal birds ranges from the coastal marshes of Maryland to the coulees of Manitoba and North Dakota. Included are eight color plates and four black-and-white pictures of the King Rail, Clapper Rail, Virginia Rail, Sora Rail, Black Rail, and Yellow Rail. Many are of birds at their nests.

The book focuses on events during trips the author makes to marshes where Black and Yellow rail nests have been found in the past. It begins with a successful trip to Elliot Island, Maryland, where Black Rails are photographed at their nests. The remainder of the book deals with the author's search to obtain photographs of Yellow Rails near Douglas, Manitoba, and at "Big Coulee" in Benson County, North Dakota.

In addition to its information on the biology and nesting habits of rails, the book contains a good deal of historical facts on ornithologists and egg collectors, or oologists, who were the first to find nests and eggs of these rare birds. There is, for instance, information on Judge John N. Clark who first found a nest of the Black Rail at Old Lyme, Connecticut in 1884 and on a young egg collector named Fred Maltby from Benson County, North Dakota, who accidently found eggs of the Yellow Rail while trudging through a marsh called "Big Coulee" in 1899.

The author devotes an entire chapter to the Reverend P. B. Peabody, an important figure in the ornithological community in the early 1900s, who was one of the most prolific collectors of Yellow Rail eggs. Like the author, Peabody made several annual treks to "Big Coulee" to photograph and collect eggs of rare bird species such as the Yellow Rail. Exerpts from Peabody's own writings provide glimpses of collecting companions such as Eugene Rolfe, John C. Knox, and "young Orlando, the shy, black-eyed son of a Pittsburgh millionaire" who helped collect eggs of Prairie Falcons in Wyoming.

Naturalists with interests in the biology of rails as well as those who enjoy reading about the lives and collecting trips of early oologists will find this book a valuable addition to their libraries.

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TABLE OF CONTENTS (*concluded*)

Book Reviews

Mailing date of the previous issue 108(4) : 19 June 1995

THE CANADIAN FIELD-NATURALIST Volume 109, Number 1 1995

Articles

Notes

News and Comment

concluded on inside back cove

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Back Numbers and Index

Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club,* 1879-1886, and The Ottawa Naturalist, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Right: Mrs. F. N. Fiscus with a bouquet of Lakeside Daisies (*Hymenoxys herbacea*) on the Lakeside Plains, an alvar on the Marblehead Peninsula of Ohio (looking south, west of the cemetary on 13 May 1946). The flowering Lakeside Daisies and Redbuds (*Cercis canadensis*) once attracted hundreds of people to the Lakeside Plains in mid-May. The area is now an extensive quarry. Mrs. Ruth E. Fiscus, daughter of the lady shown in the photo, received the Ohio Conservation Achievement Award in 1989, along with coworker Mrs. Colleen Taylor, for the successful campaign to protect the last major population of Lakeside Daisies in the United States, where the species is currently designated as "threatened". Photo used with permission of Mrs. Ruth E. Fiscus. Left: Flower of Lakeside Daisy photographed during a partial second blooming in September 1989 on the Lakeside Daisy State Nature Preserve, Marblehead Peninsula, Ohio. Photo by P. M. Catling. See review article by P. M. Catling and V. R. Catling on the alvars of the Great Lakes region, pages 143–171.

The Canadian Field-Naturalist

Volume 109, Number 2 April–June 1995

A Review of the Alvars of the Great Lakes Region: Distribution, Floristic Composition, Biogeography and Protection

PAUL M. CATLING, and VIVIAN R. BROWNELL

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Catling, Paul M., and Vivian R. Brownell. 1995. A review of the alvars of the Great Lakes region: Distribution, floristic composition, biogeography, and protection. Canadian Field-Naturalist 109(2): 143–171.

Alvars are naturally open areas of thin soil over essentially flat limestone or marble rock with a more or less sparse vegetation cover of shrubs and herbs with trees absent or at least not forming a continuous canopy. Drought and extremes of soil moisture are major factors limiting tree cover. Alvars are important as sites for (1) the protection of biodiversity including threatened plant communities, rare and threatened species of flora and fauna, and germplasm of crop relatives; (2) biological research and environmental monitoring; and (3) ecotourism. Approximately 85% of alvar sites and more than 90% of alvar landscape area in the Great Lakes region is in southern Ontario. With the exception of small isolated areas, most notably western Lake Erie and Lake Champlain area, the alvars of the Great Lakes region occur near the contact line of the granitic Canadian Shield upland with the Ordovician and Silurian limestones and dolomites. The main area of occurrence extends from the north shore of Lake Michigan east to the islands of northern Lake Huron, such as Drummond Island, east across Manitoulin Island, southeast to the south end of Georgian Bay, east to the Lake Simcoe area and the Carden limestone plain, discontinuously east to the Napanee limestone plain between Trenton and Kingston, then, following a gap due to the Frontenac axis of granitic rocks, and/or Lake Ontario, appearing again in New York State at the east end of Lake Ontario and on the Smiths Falls limestone plain in the Ottawa Valley. A list of 347 vascular plant taxa found on alvars in seven alvar regions is included based on examination of 59 sites in Ontario, one in Ohio and three in New York State, as well as on the literature and on personal communications. On the basis of floristic composition and environmental factors, alvars may be divided into two types: shoreline alvars along rivers and lakes and plateau alvars. Four major plant communities related to soil depth and moisture availability are identified on plateau alvars: alvar grassland, alvar pavement, alvar savanna and pavement ridge. Biodiversity is highest on the alvars of western Lake Erie, Manitoulin Island and the Napanee Plain. The alvar floras of seven regions are apparent as three major groups in both a phenogram and in the principal coordinate plot derived from a matrix of Jaccard's coefficients: (1) the western Lake Erie alvars with a proportionally high component of plant species occurring to the south, but a relatively small proportion occuring to the north; (2) the alvars of the Bruce Peninsula and Manitoulin Island with a high proportion of northern and endemic plant species at the expense of southern species; and (3) the alvars of central Ontario, eastern Ontario and northern New York with a moderate representation of plant species occurring also to the north, but the major proportion being southern species. The endemics and boreal elements of the northern Lake Huron alvars are probable relicts of the *Picea* Parkland and tundra-like environments that existed in front of the Wisconsin glacier more than 9000 years ago, and the alvars of this region are of great interest in their apparent similarity to the periglacial environment. The primarily western species on alvars may have also originated from this environment or may have migrated along pathways of open habitat that extended from western North America eastward into the Great Lakes region during glacial or postglacial times. Although some of the best alvars in the Great Lakes region are protected, not enough sites are protected to achieve adequate representation.

Key Words: Alvar, savanna, flora, biodiversity, phytogeography, biogeography, endemic species, rare species, Great Lakes, Ontario, Canada, Ohio, New York, United States.

Alvars are naturally open areas of thin soil over essentially flat limestone or marble rock with a more or less sparse vegetation cover of shrubs and herbs with trees absent or at least not forming a continuous canopy (Figure 1). The term was evidently first applied in North America to areas near Kingston, Ontario, by R. E. Beschel in the late 1960s (Catling et al. 1975), but has long been in use for the limestone barrens of the Baltic countries. Inherent in the use of the term "alvar" by botanists is the recognition of a distinctive vegetation in terms of both species (Catling 1995) and associations (e.g. Catling et al. 1975; Reschke 1990; Belcher et al. 1992) and prominence of periodic drought (Figure 2), slope and exposure in controlling zonations and vegetation cover (e.g. Stephenson 1983; Stephenson and

FIGURE 1. A portion of the alvar at Odessa on the Napanee Limestone Plain near Kingston, Ontario. Limestone pavement with gravel and moss cushions (*Tortella tortuosa*, *Tortula ruralis*) is evident in the lower portion of the photo. The grassland is composed of *Panicum flexile*, *Panicum philadelphicum*, *Poa compressa*, and *Sporobolus vaginiflorus*. Surrounding trees are Eastern White Cedar. Photo by P. M. Catling, September 1989.

FIGURE 2. Dead Eastern White Cedar (*Thuja occidentalis*) trees killed by severe drought around the edge of the Asseltine Alvar near Kingston, Ontario. Photo by P. M. Catling, August 1989.

Herendeen 1986; Reschke 1994*). Alvars may occur as narrow bands along the shores of lakes and rivers or as extensive complexes of large openings on limestone or marble plateaus.

The Nature Conservancy has listed "open alvar"; i.e., alvar grassland and pavement; as globally imperiled and imperiled in Ontario. The "Jack Pine limestone pavement savanna", the "Red Cedar limestone savanna" and the "Chinquapin Oak limestone savanna" are considered critically imperiled globally (Nature Conservancy of Canada, personal communication). Apart from the very restricted plant communities and rare plant species, a significant fauna is also characteristic. Alvars are important as sites for protection of germplasm of crop relatives, as sites for research and environmental monitoring. Increasing interest in the identification and protection of alvars, as well as increased interest in research concerning their history and ecology has required that a general overview be available, the only work satisfying this need (Catling et al. 1975) being out of date and not covering the entire Great Lakes region. Specifically, the purpose of the present work is to summarize information on the distribution, floristic composition, biogeography and protection of alvars in the Great Lakes region, thus providing the general overview necessary for both research and development of an adequate system of protected sites.

*See Documents Cited section which preceeds Literature Cited.

Methods

Field study included visiting approximately 120 sites in Ontario and several in Ohio and New York. At each of 59 moderate to good quality Ontario sites, one Ohio site and three New York sites visited (Figure 10; Appendix 1), lists of species were compiled and notes were made on major associations. "Good quality" sites were defined as those having a relatively high native plant diversity, native plant communities representative of the landform, and a minor component of alien species. Information on additional sites was obtained from the literature and personal communications.

The estimated number of alvar sites and original amount of alvar habitat in various regions was estimated through reference to aerial photographs, topographic, soil landscape, and physiographic maps. Here sites are defined as openings or complexes of openings at least 0.5 hectares in extent and separated by more than 2 km. Sites were identified on the basis

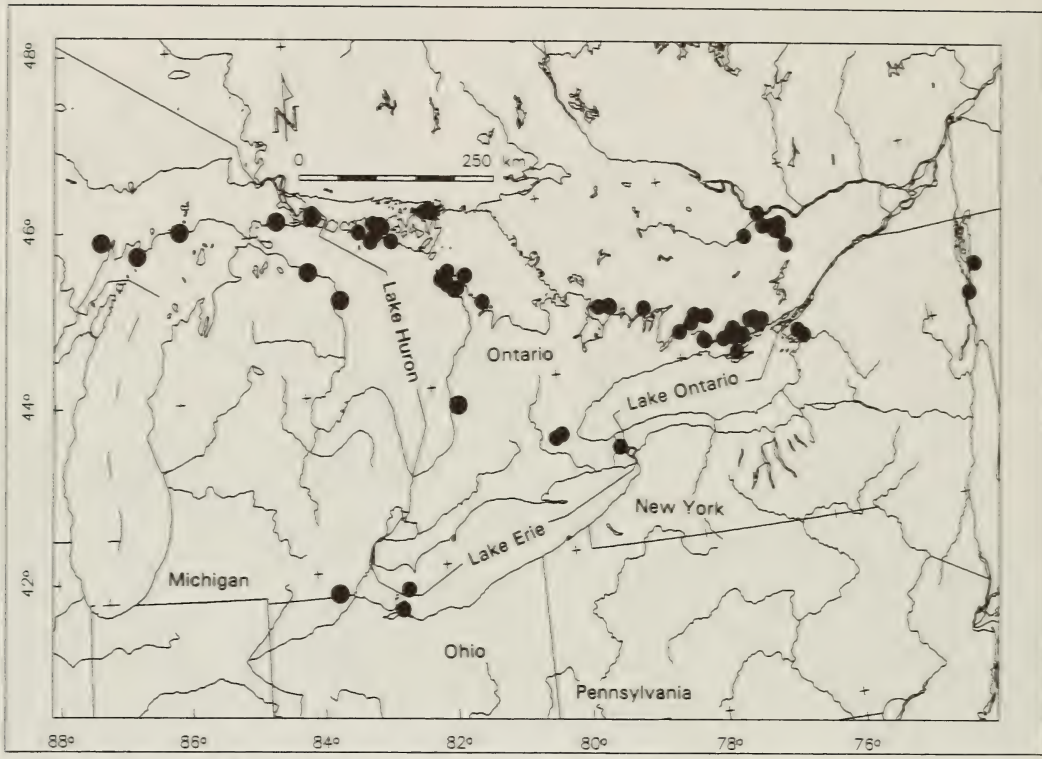

FIGURE 3. Distribution of alvars (dots) in Great Lakes region (83 sites) for which information on species composition is available from Natural Resources, Heritage or Nature Conservancy offices, or from researchers.

of natural vegetation suggesting open habitat prior to human influence.

Relationships among regions in terms of their alvar floras were evaluated using UPGMA (unweighted pair group method with arithmetic averaging) clustering of Jaccard's coeffients and principal coordinate analysis with minimum spanning tree, both derived from the cumulative species lists for three or more sites within each region. Details on the statisticial procedures may be found in Pielou (1984). Analyses were done with NTSYS-pc version 1.6 (Rolfe 1990).

Results and Discussion

Distribution and Extent of Documented Alvars

With the exception of small isolated areas (e.g., western Lake Ontario, western Lake Erie, and Lake Champlain area), the alvars of the Great Lakes region occur near the contact line of the granitic Canadian Shield upland with the Ordovician limestones and dolomites (Figure 3). The main area of occurrence extends from the north shore of Lake Michigan east to the islands of northern Lake Huron, such as Drummond Island, east across Manitoulin Island, southeast to the south end of Georgian Bay, east to the Lake Simcoe area and the Carden limestone plain, discontinuously east to the Napanee limestone plain between Trenton and Kingston, then, following a gap due to the Frontenac axis of granitic rocks, and/or Lake Ontario, appearing again in New York State at the east end of Lake Ontario and on the Smiths Falls limestone plain in the Ottawa Valley. It is very roughly estimated that 252-287 alvar sites currently exist in the Great Lakes Region. Additional field studies are required to provide more accurate figures (Table 1).

Alvar habitats probably always occupied a relatively small portion of southern Ontario. The largest area was in Manitoulin District where the total area undoubtedly exceeded 400 km^2 (Table 1). Most of the alvars on the Bruce Peninsula and in Manitoulin District are still present although some in the latter region are degraded through grazing. North of Kirkfield on the Carden limestone plain, alvar habitats may have exceeded 220 km^2. Most of these are still present, but subject to various levels of grazing. Possibly some of the sites that appear to be degraded alvars, were White Pine forests in pre-settlement times, the alvar-like habitats developing secondarily following clearing and fire. Certainly the Napanee Plain contained the second largest area of alvar outside of Manitoulin. Estimates for the Napanee Plain

TABLE 1. Approximate areas of original alvar habitat and estimated number of existing sites in various portions of the Great Lakes Region.

Region	Original area (km^2)	Estimated number of existing sites
Northern Michigan	50	15–20
Western Lake Erie (Ohio, Michigan, Ontario)	15	20
Northwestern New York	30	10–15
Vermont	2	2
Napanee Plain, Ontario	300	30
Smiths Falls Plain, Ontario	25	15
Carden Plain, Ontario	220	35
Bruce Peninsula, Ontario	50	25
Manitoulin Island, Ontario	400	75–100
Other smaller areas in Ontario (Flamborough Plain, Niagara Region, central Ontario)	30	25
Total:	1122	252–287

and the Smiths Falls Plain are difficult due to both urbanization and heavy agricultural use of the landscape. Considering the estimates in Table 1, the minimum area of alvar vegetation present in the Great Lakes region prior to settlement was probably 1100 km^2, whereas the maximum was probably less than 1500 km^2.

Regional Perspectives

Michigan: —- In the lower peninsula, a small alvar area existed in the vicinity of Sterns Road, southwest of Detroit (A. A. Reznicek, personal communication). While most of this area was destroyed through quarrying, a remnant still exists. The only other alvars documented in the lower peninsula are on Devonian bedrock (Dorr and Eschman 1984) in the vicinity of Rogers City and Alpena, and on Thunder Bay Island, northern Lake Huron (Penskar and Ludwig 1981*; D. A. Albert personal communication). The most extensive region of alvar occurrences in the state is in the upper peninsula (L. Scringer, D. A. Albert, personal communication), particularly a band on mostly Silurian bedrock (Ehlers and Kesling 1957; Reed and Daniels 1987) extending from Drummond Island to Cedarville, west to Seul Choix Point and the Garden Peninsula. The best known site is Drummond Island where the extensive Maxton Plains (Stephenson 1983) are situated on Ordovician bedrock whereas the alvars on the the south side and central portion of the island are on Silurian bedrock. Alvars also exist further to the west in the upper peninsula on Ordovician bedrock (Hussey 1952) along the Escanaba River (e.g., Chapman 1986).

New York State: — Within New York State, on the Chaumont limestones of Jefferson County, at the northeastern end of Lake Ontario, alvars occur in seven general areas. There are numerous large and small openings within the larger sites. These large sites include the Chaumont Barrens, the Limerick Cedars area and the Lucky Star area. Limerick Cedars was discovered accidently when a car carrying some New York State Museum botanists broke down near Limerick, and they noticed the Northern Dropseed Grass (*Sporobolus heterolepis)* growing beside the road. Explorations nearby disclosed some natural glades where the rare grass and other restricted plants were well established. Subsequently a study of aerial photographs and geological maps of the general area by Carol Reschke of the New York Natural Heritage Program resulted in the discovery of the Chaumont Barrens area and several other sites, and the first recent station of the western Prairie Smoke (*Geum triflorum)* in New York State (Reschke 1990). A rare moss, *Scorpidium turgescens*, was discovered in the rocky, periodically moist, Tufted Hairgrass (*Deschampsia caespitosa*) grassland on the Chaumont Barrens (Slack et al. 1985). Lists and descriptions are available for these sites (Gilman 1988*, 1990, 1995*; Reschke 1988*, 1990; Zaremba and Mitchell 1990), and Limerick Cedars is particularly well known as a result of Gilman's (1995*) thesis work. Other high quality alvars in the same region include Burnt Rock Barrens, Route 9 Alvar, Star School Road Alvar and Three Mile Creek Alvar (Reschke 1995, personal communication). These are less well known and are not listed in Table 1, nor mapped. Information on their significant features is available from the Biological Conservation Data System in the New York Natural Heritage Program. Shoreline alvars also occur as narrow bands along some of the rivers draining into the eastern end of Lake Ontario, and on Galloo Island, Stony Island and Stony Point in eastern Lake Ontario, but some of the island sites may be degraded due to previous grazing (Hainault 1966, 1968*).

Small alvar areas may have once occurred around Buffalo, but these evidently graded into habitats with

largely prairie-like vegetation called the Buffalo Plains (Zenkert 1934). Some other open areas with limestone near the surface in New York State, such as the Rush Oak openings south of Rochester near West Rush, have a relatively substantial soil development, are undulating, and are dominated by tall prairie grasses, thus being unlike the majority of alvars, and perhaps better classified with prairies. Small alvars may exist in association with the limestone woodlands along the Onondaga Escarpment between Rochester and Buffalo and in the Lake Champlain area.

Ohio: — In northern Ohio, alvars may have existed in the region of Toledo, along the Maumee River, and on some limestone outcrops to the east, but these have apparently been destroyed or badly degraded. Small areas of alvar habitat exist on the shorelines of some of the western Lake Erie Islands. The largest area of alvar in northern Ohio was on the Marblehead Peninsula south of the hamlet of Lakeside and was for a long time known as the Lakeside Plains. Most of the plains were destroyed by quarrying (Ahrens 1984; Ohio Department of Natural Areas and Preserves 1994*), however remnants still exist. A rich native flora survives in some of these remnants and has also colonized some of the old quarries in the vicinity.

Ontario: — Six main alvar regions exist in Ontario: Manitoulin Island, Bruce Peninsula, western Lake Erie, Carden Plain, Napanee Plain and Smiths Falls Plain. The best known sites in Ontario are Stone Road Alvar on Pelee Island (Duncan 1973; Campbell and Reznicek 1977; Oldham 1983*; Oldham and Kamstra 1989*; Kirk 1994), the Burnt Lands Alvar and Shirley's Bay near Ottawa (White 1979; Brunton 1980*, 1986*; Belcher 1992*; Belcher et al. 1992), the Camden East Alvar and Salmon River Alvars west of Kingston (Schlesinger 1980* and Norris 1994* respectively), the Clay Bank Alvar near Arnprior (Brunton 1988), and Misery Bay on Manitoulin Island (Macdonald 1980*). Within the Smiths Falls limestone plain, a few small, disturbed alvars or alvar-like communities exist that are not listed in Appendix Table 1, including Stony Swamp (Brunton 1982*) and Marlborough Forest (White 1985*, 1989*).

In addition to the six main alvar regions in southern Ontario already alluded to above and initially described in Catling et al. (1975), a few smaller areas with alvars exist. In the region between the Carden Plain and the Napanee Plain where most of the limestone is buried under the Dummer Morraine, a few isolated limestone exposures occur with small alvars. They are also found west of the Carden Plain in Simcoe County, but those examined to date are not rich in characteristic flora (Catling 1995). Alvars also exist in parts of Prince Edward County: on Long Point and on the islands of eastern Lake Ontario (Timber, Swetman, Main Duck, Yorkshire), but have only been generally described and some of the examples are degraded due to previous grazing (Hainault 1966, 1968*).

Characteristic alvar plants such as *Geum triflorum* and Field Chickweed (*Cerastium arvense*) existed until the mid-1970s in Waterloo County, but the substrate was deep, gravelly overburden, and these sites were probably not true alvars. Sites that once existed along the Onondaga escarpment between Fort Erie and Hagersville (Catling *et al.* 1975) appear to have been largely destroyed. A few sites also exist on the largely forested Flamborough limestone plain at the western end of Lake Ontario, and these are currently under study (A. Goodban, personal communication). Limited alvar habitat also existed on the top of the Niagara Gorge north of Niagara Falls (Zenkert 1934), where there are still a few small areas dominated by Little Bluestem (*Schizachyrium scoparium*) with presumably native occurrence of Rough Dropseed (*Sporobolus asper*), and with characteristic species such as Smooth Aster (*Aster laevis*), Pringle's Aster (*Aster pilosus* var. *pringlei*), sedges (*Carex crawei*, *C. umbellata*), Houstonia (*Hedyotis longifolia*), and Small Skullcap (*Scutellaria parvula*)[personal observations]. Areas of shallow soil over limestone also exist along some rivers in southern Ontario and in some places along the shores of the Great Lakes such as the eastern end of Lake Erie (see under "Shoreline Alvar" below).

Québec: — Although limestone exists at the surface in the Lake Champlain area, alvars have been reported in Québec only from the Aylmer area in the upper Ottawa valley (Huggett 1993). The sites currently documented in this area are not as rich in characteristic species as those of the nearby Smiths Falls limestone plain of Ontario, but their diversity may have been reduced through extreme grazing pressure.

Vermont: — In Vermont small alvar-like sites exist along the shores and on tops of limestone bluffs near Lake Champlain. The two most notable sites are Twin Bridges and Button Bay State Park. Among the notable species at these sites are *Scutellaria parvula*, Ram's-head Lady-slipper (*Cypripedium arietinum*), *Sporobolus asper*, Golden Corydalis (*Corydalis aurea*), New Jersey Tea (*Ceanothus americana*) and Blue Grass (*Poa glauca*) (E. Marshall, personal communication).

Floristic composition and ecological factors

A complete list of 347 native vascular plant taxa found by us on alvars of the Great Lakes region is provided in Appendix 2. Of these, 86 species are considered characteristic based on their occurrence in at least 50% of the 63 alvars examined. Extent of confinement of vascular plants to alvars in Ontario

has been recently discussed elsewhere (Catling 1995).

Useful general descriptions of alvar plant associations are available for various sites (e.g., Catling et al. 1975; Reschke 1990; McKay-Kuja and Kavanagh 1992*; Belcher et al. 1992; Norris 1994*; and see under "Regional Perspectives"). Extensive and detailed quantitative studies are lacking. Problems in developing a predictive model of alvar vegetation within the Great Lakes Region include regional variation, frequent intergradation of plant associations, and capability of any one of several frequent plant associates to act as a dominant.

Plateau Alvar

Vegetation of alvars on limestone or marble tableland located inland from shorelines frequently has a particular pattern of parallel openings and parallel bands of forest (Figure 4, top). The forested areas often correspond to ridges with cracks or low escarpment edges. The long narrow bands of forest following the ridges ("curtain forests", Figure 4, bottom), may also be a result of long bands of sand and gravel deposited on otherwise exposed limestone pavement. Soil depth and the extent of periodic wetness are both important factors in relation to the kinds of plant associations on alvars. Four major associations can be recognized, but some sites are without one or

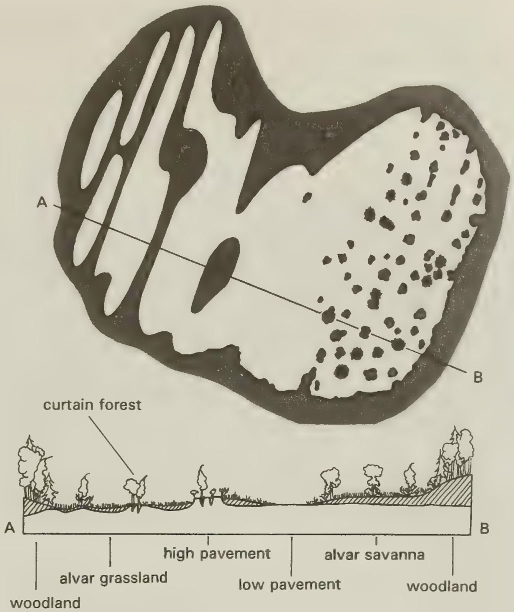

FIGURE 4. Diagramatic cross-section of a plateau alvar complex with alvar grasslands, high pavement (pavement ridge), low pavement, and alvar savanna with surrounding woodland and curtain forest.

FIGURE 5. Low pavement on the alvar at Misery Bay, Manitoulin Island, with *Sporobolus heterolepis*, *Deschampsia caespitosa*, and *Potentilla fruticosa* growing in cracks between the pavement blocks. Photo by P. M. Catling, June 1994.

FIGURE 6. Alvar savanna association at the Foxey Savanna on Manitoulin Island. The grassland is dominated by *Poa compressa*, *Senecio pauperculus* and *Geum triflorum* with scattered *Juniperus communis*. The trees are Bur Oak (*Quercus macrocarpa*). Photo by P. M. Catling, June 1994.

two of them. For example, where the underlying limestone readily degrades to a flaky parent material for soil development the Bur Oak-Red Cedar savanna may be well developed, while pavement edge and pavement scrub associations may be non-existent. The larger alvar complexes are the most likely to contain a complete range of potential plant assemblages. Some good examples of this are the Chaumont Barrens in New York State, and the Cloche and Misery Bay complexes on Manitoulin Island.

The more open phases of plateau alvar may be divided into alvar grasslands and pavements (Figures 4, 5 and 7). Belcher et al. (1992) used the terms "meadows" and "rock flats" respectively in reference to these two major divisions. Within each division several subdivisions are possible based largely on dominance of single species which in turn is associated with moisture levels. The moisture is periodic and even the wettest sites are subject to complete drying out.

Communities with trees may be classified as either limestone savannas or pavement ridges (Figures 4 and 6). These, and for that matter the open phases, are all prone to transition zones, which are sometimes extensive.

1. Alvar Grasslands

The dominant species in alvar grasslands (Figure 7) are related to both soil depth (1-10 or more cm) and moisture (the latter having to do with elevation as well as soil depth). Belcher et al. (1992) found four subdivisions of meadow in the Burnt lands alvar on the Smiths Falls limestone plain. One was dominated by *Sporobolus heterolepis*, another by *Carex crawei*, the third by Panic Grass (*Panicum philadelphicum*) and the fourth by another Panic Grass (*Panicum flexile*). Elsewhere Poverty Oat Grass (*Danthonia spicata*), *Schizachyrium scoparium*, *Carex scirpoidea* and/or Blue Grama Grass (*Bouteloua curtipendula*) may be at least localized dominants on drier sites. In the wettest sites the associations are dominated by some combination of *Carex sartwellii*, *Carex lanuginosa* and Fowl Manna Grass (*Glyceria striata*). In periodically wet sites where the soil is only a few centimeters deep, *Deschampsia caespitosa* is frequently a dominant species. Canada Blue Grass (*Poa compressa*) is an abundant alvar grassland dominant with a broad moisture range that may be more characteristic of disturbed sites. It is not yet absolutely clear whether or not this species is introduced. Spikerush (*Eleocharis compressa*) is a local dominant of lower,

FIGURE 7. Extensive alvar grassland dominated by *Sporobolus heterolepis* on Little Cloche Island in the North Channel of Lake Huron. Sites like this one are believed to be closely related to the continuous periglacial grasslands that existed in the Great Lakes region until 9000 years ago. Photo by P. M. Catling, June 1991.

periodically moist sites but may become a widespread dominant following grazing since it is often avoided by cattle in favour of grasses.

Various herbs are sometimes frequent or even co-dominant in alvar grasslands including Long-fruited Anemone (*Anemone cylindrica*), Low Bindweed (*Calystegia spithamea*), *Cerastium arvense*, Bastard Toadflax (*Comandra umbellata*), Common Strawberry (*Fragaria virginiana*), *Geum triflorum*, Seneca Snakeroot (*Polygala senega*), Prairie Cinquefoil (*Potentilla arguta*), Heal-all (*Prunella vulgaris*), Early Buttercup (*Ranunculus fascicularis*), *Scutellaria parvula*, Balsam Ragwort (*Senecio pauperculus*), Early Goldenrod (*Solidago juncea*), Gray Goldenrod (*Solidago nemoralis*), Heath Aster (*Virgulus ericoides*) and *Zigadenus glaucus*.

A correlation of vegetation pattern, particularly woody species, with both hydrological and other factors, persuaded Reschke (1994*) that both drought and inundation prevent invasion of woody species into alvar grasslands. This combined effect is probably most pronounced in periodically very wet sites such as *Deschampsia caespitosa*, *Carex lanuginosa*, or *Carex sartwellii* associations. Regular summer droughts may be enough to prevent invasion of woody species in the driest sites such as *Bouteloua curtipendula* or *Schizachyrium scoparium* associations. Periodic, catastrophic drought effects may be the most important factor in excluding woody species from sites of intermediate moisture level such as many *Sporobolus heterolepis* or *Poa compressa* grasslands.

2. Pavements and Pavement Edges

The pavement edge is characterized by soil less than 2 cm deep (Figure 1). Belcher et al. (1992) found three major groupings within this category on the Burnt Lands Alvar complex in eastern Ontario. These were dominated by *Panicum philadelphicum*, by both *Panicum philadelphicum* and Early Saxifrage (*Saxifraga virginiensis*) or by *Saxifraga virginiensis* alone.

The floristic composition of pavement is influenced by variation in elevation and slope, hydrological factors that lead to local variation in moisture retention. Lower sites that are sometimes temporary pools have Ticklegrass (*Agrostis scabra*), Willowherb (*Epilobium coloratum*), Hedge-hyssop (*Gratiola neglecta*) and Purslane (*Portulaca oleracea*). The moss *Physcomitrium pyriforme*, the liver-

wort *Riccia sorocarpa*, and the algae *Nostoc commune* are also characteristic of periodically wetter pavements. Rock-cress (*Arabis hirsuta*) and the rare Mousetail (*Myosurus minimus*) appear to occupy sites of intermediate moisture availability. False Pennyroyal (*Trichostema brachiatum*) also appears to fall into this category but has a wider moisture tolerance. The drier pavements with a similar soil depth of less than 2 cm have Rock Sandwort (*Minuartia michauxii*), Mock Pennyroyal (*Hedeoma hispida*), *Saxifraga virginiensis* and Rock Spikemoss (*Selaginella rupestris*) often in association with moss cushions comprised of either *Tortella tortuosa*, *Tortula ruralis* or *Ceratodon purpureus*. These moss cushions are very important to the community as a whole since they accumulate water like sponges following a rain. Although there appears to be little above-ground competition in these very open associations, recent studies have elucidated below-ground competition (Belcher 1992*).

Many species are characteristic of pavements which frequently lack single dominants and are often the richest sites on alvars with up to 20 species in a m^2 quadrat. Characteristic species, in addition to those mentioned above, include *Calamintha arkansana*, Nodding Chickweed (*Cerastium nutans*), Draba (*Draba nemorosa*, *D. reptans*), Cranesbill (*Geranium bicknellii*, *G. carolinianum*), *Lepidium* spp., Forget-me-not (*Myosotis verna*), *Panicum flexile*, *Panicum philadelphicum*, *Poa compressa*, Rough Cinquefoil (*Potentilla norvegica*), *Scutellaria parvula*, and Ensheathed Dropseed (*Sporobolus vaginiflorus*). The interaction of various factors such as moisture retention (Reschke 1994*), amount of frost heaving (Reschke 1994*), and root competition (Belcher 1992*), in controlling vegetation composition of pavements, requires more study.

Where small cracks exist in the exposed rock or where the rock has decayed into a gravelly substrate as on the North Channel alvars of Manitoulin Island, various species may gain a foothold such as Wild Chives (*Allium schoenoprasum*), Lakeside Daisy (*Hymenoxys herbacea*), Blazing Star (*Liatris cylindracea*), Beard-tongue (*Penstemon hirsutus*), and others. Deeper cracks accomodate grasses (Figure 5). The largest cracks afford the moisture for woody vegetation characteristic of mesic sites, and limestone ferns characteristic of shaded cliffs and talus, thus grading into "Pavement Ridge" vegetation.

3. Alvar Savanna

Alvar or limestone savanna is savanna in the sense of having the canopy incomplete and more than 50% open (Clements 1928; Curtis 1959, page 330) (Figure 6). Periodic fires may reduce the shrub layer. At least five major types of alvar savanna may be identified:

(1) Oak Limestone Savanna. Bur Oak (*Quercus macrocarpa*) is the most frequent dominant in these savannas (Figure 6), but other oaks (*Q. alba*, *Q. borealis*) are dominant at some sites, and Shagbark Hickory (*Carya ovata*) may also be present (e.g., Catling and Catling 1993). Like the Jack Pine Limestone Savanna, these savannas are distinctive in having certain species not present, or at least scarce in the fully open areas and in the surrounding forest. Examples of some characteristic species that seem to do best in the partial shade are Cooper's Milk-vetch (*Astragalus neglectus*), Canada Brome (*Bromus pubescens*), *Carex cephalophora*, *Carex pensylvanica*, *Carex siccata*, Northern Bedstraw (*Galium boreale*), Robin's-plantain (*Erigeron pulchellus*), Woodland Sunflower (*Helianthus divaricatus*), Bottle-brush Grass (*Hystrix patula*), False Melic Grass (*Schizachne purpurascens*) and Yellow Pimpernel (*Taenidia integerrima*) (e.g., Catling and Catling 1993). In the more open areas a combination of some of these species with species more characteristic of open alvar is sometimes present. Shrubs such as *Ceanothus americana*, Gray Dogwood (*Cornus racemosa*), Common Juniper (*Juniperus communis*), Fragrant Sumac (*Rhus aromatica*), Snowberry (*Symphoricarpos albus*), and Downy Arrow-wood (*Viburnum rafinesquianum*) are often dominant or subdominant in semi-shaded areas.

(2) Chinquapin Oak (*Quercus muehlenbergii*)-Blue Ash (*Fraxinus quadrangulata*) Limestone Savanna. At Stone Road Alvar on Pelee Island the savanna trees include White Oak (*Quercus alba*), Swamp White Oak (*Q. bicolor*), *Q. muhlenbergii* and *Fraxinus quadrangulata* with some *Celtis occidentalis*. Thickets of Prickly Ash (*Zanthoxylum americanum*) harbour the provincially rare Downy Wood Mint (*Blephilia ciliata*).

(3) Jack Pine (*Pinus banksiana*) Limestone Savanna. On the Bruce Peninsula and Manitoulin Island, Jack Pine is a dominant tree of alvar savannas, with an understory that includes Coreopsis (*Coreopsis lanceolata*), *Cypripedium arietinum* and Dwarf Lake Iris (*Iris lacustris*).

(4) Eastern White Cedar (*Thuja occidentalis*) Limestone Savanna. Eastern White Cedar may occur in a scattered association with White Pine (*Pinus strobus*) and White Spruce (*Picea glauca*). Wild Lily-of-the-valley (*Maianthemum canadense*) and Barren Strawberry (*Waldsteinia fragarioides*) are characteristic of the shaded portions of this type of limestone savanna. Few extensive examples have been observed and this association is frequently little more than an edge.

(5) Red Cedar (*Juniperus virginiana*) Limestone Savannna often grades into Bur Oak Limestone Savanna. Among the characteristic herbs are Heart-leaved Aster (*Aster cordifolius*), *Carex backii*, *Carex siccata*, *Carex pensylvanica*, *Comandra umbellata*, *Fragaria virginiana*, Wild Bergamot (*Monarda fistulosa*), *Poa compressa* and moss *Thuidium abiet-*

inum. This is also the habitat of the very rare *Carex juniperorum*. Prominent shrubs include *Rhus* spp. and *Juniperus communis*.

4. Pavement Ridge

The pavement ridge is usually elevated and with little or no soil, but supports tree and shrub cover as a result of deep, moist cracks where trees and shrubs can establish. Depending on the size of the crack and the degree of moisture in it, the trees and shrubs may be species of dry to wet sites. *Pinus banksiana, Quercus macrocarpa, Quercus muehlenbergii, Juniperus communis, Rhus aromatica* and *Juniperus virginiana* are characteristic of drier places on pavement ridges, whereas *Thuja occidentalis*, Basswood (*Tilia americana*), and *Cornus racemosa* are characteristic of more mesic microsites. *Cornus stolonifera, Fraxinus* spp., and Meadowsweet (*Spiraea alba*) arise from the deepest cracks. The cracks frequently have ferns such as Marginal Wood Fern (*Dryopteris marginalis*), Maidenhair Spleenwort (*Asplenium trichomanes*) and Northern Wood Fern (*Cystopteris fragilis*). In some locations Purple-stemmed Cliff-brake (*Pellaea atropurpurea*) occurs on the flat rock or on the crevice edges, and Limestone Oak Fern (*Gymnocarpium robertianum*) is present at one site on the Bruce Peninsula. *Saxifraga virginiana* is often prevalent in the shallow soil with various other species characteristic of pavement as described above. On the Napanee Plain, Wood Spurge (*Euphorbia commutata)* is sometimes prevalent on very shallow soil in association with *Bouteloua curtipendula* and *Poa compressa*, but it is highly sporadic in its appearance, some years being abundant, other years being totally absent.

Pavement ridge vegetation differs from savanna vegetation in being mostly limestone pavement with much exposed rock, the trees confined to cracks that are often wide and open. Savanna occurs on deeper soils where little rock is exposed and the location of cracks if present is less clear. Pavement ridges may be divided into a number of different groups on the basis of tree dominants. White Spruce (*Picea glauca*) or Trembling Aspen (*Populus tremuloides*) are often dominants in the upper Lake Huron region. Other trees here include White Birch (*Betula papyrifera*), *Pinus banksiana*, *Pinus strobus* and *Thuja occidentalis*. Oaks and Red Cedar (*Juniperus virginiana*) are more prevalent further to the south.

Shoreline Alvar

Areas of shallow soil over limestone or marble exist as bands along the shores of rivers and lakes, where their low position on the landscape and periodic flooding results in more moist spring conditions than exist on plateau sites. Although having much in common with higher plateau alvars, the periodically flooded pavements are apparently sufficiently different in composition and ecological processes that they should be recognized as a distinct type.

Examples of rivershore alvars include sites along the Escanaba River in Michigan (e.g. Chapman 1986), the Ausable and Maitland Rivers draining the Ontario shore of Lake Huron (Oldham et al. 1993*), the Black River draining into western Lake Ontario, and the Ottawa River in eastern Ontario. The vegetation of these relatively narrow bands is similar to that of plateau alvars but includes some prairie or fen elements and other unusual species. On the limestone flats of the Maitland River for example, *Schizachyrium scoparium*, Big Bluestem (*Andropogon gerardii*), Muhly Grass (*Muhlenbergia richardsonis*), False Asphodel (*Tofieldia glutinosa*), Hairy Valerian (*Valeriana edulis* ssp. *ciliata*), Prairie Golden Alexanders (*Zizia aptera*), and Indian Plantain (*Cacalia plantaginea*) are present (Oldham et al. 1993*; A. A. Reznicek, personal communication). These open river flats were recognized long ago by MacNab (1835) as an important location for rare plants. At Shirleys Bay on the Ottawa River (*see* Brunton 1980*), a periodically flooded limestone rivershore is situated adjacent to non-flooded alvar. The rivershore includes species such as *Andropogon gerardii* and Sneezeweed (*Helenium autumnale*), not found on the adjacent, non-flooded alvar dominated by Prairie Dropseed (*Sporobolus heterolepis*).

The periodically flooded and wave-washed limestone shores of Lakes Erie (Zenkert 1934), Huron and Ontario also have distinctive shoreline alvar that frequently grades into characteristic plateau alvar. The gradually sloping limestone shores of upper Lake Huron region that are periodically flooded and where there is frequently seepage through limestone gravel have a number of species not generally encountered in non-flooded alvars away from the shore, but rather characteristic of fens, shores and seeps. Included here are Northern Reed Grass (*Calamagrostis inexpansa*), *Carex garberi*, *Helenium autumnale*, Kalm's St. John's-wort (*Hypericum kalmianum*), Alpine Rush (*Juncus alpinoarticulatus*), Baltic Rush (*Juncus balticus* var. *littoralis*,), Knotty Rush (*Juncus nodosus*), Flax (*Linum medium* var. *medium*), Kalm's Lobelia (*Lobelia kalmii*), Ninebark (*Physocarpus opulifolius*), Butterwort (*Pinguicula vulgaris*), Silverweed (*Potentilla anserina*), Bird's-eye Primrose (*Primula mistassinica*), Beak-rush (*Rhynchospora capillacea*), Hoary Willow (*Salix candida*), Pitcher-plant (*Sarracenia purpurea*), Northern Meadow Spikemoss (*Selaginella apoda*) and Ohio Goldenrod (*Solidago ohioensis*). Many species characteristic of alvars are also present including Wild savory (*Calamintha arkansana*), *Carex crawei, Carex scirpoidea, Hedyotis longifolia*, Prostrate Juniper (*Juniperus horizontalis*), *Schizachyrium scoparium*, Balsam Ragwort (*Senecio pauperculus*), Gray Goldenrod (*Solidago nemoralis*), *Sporobolus heterolepis*, Violet (*Viola nephrophylla*) and White Camas (*Zigadenus glaucus*).

Alvar-like Communities

Wisconsin prairies on dry, thin soil on limestone ridges have much in common with alvars including a prominence of grasses such as *Bouteloua curtipendula*, *Schizachyrium scoparium*, *Sporobolus heterolepis* and herbs such as *Aster ericoides*, *Geum triflorum*, *Solidago nemoralis* and Hoary Vervain (*Verbena stricta*). However there are also many species that do not occur on alvars to the east, including many plants characteristic of a broad range of prairie habitats (Curtis 1959). The same appears to be true of sites in central Ohio (A. W. Cusick, personal communication) and Illinois (Sheviak 1981; McFall 1984) and apparently also the Missouri glades (Erickson et al. 1942). Although these sites are regarded as prairie, the fact is that xeric prairie on shallow soil over limestone is similar to some kinds of alvar and cedar glade vegetation. Wisconsin prairie vegetation is classified primarly by correspondance with moisture avalability (Curtis 1959), whereas both moisture availability and soil depth are important correlates of alvar vegetation.

In Kentucky and Tennessee particularly, plant communities exist that are very similar to the alvars of the Great Lakes region. They are invariably surrounded by Red Cedar (*Juniperus virginiana*) and are called "Cedar Glades" (e.g., Freeman 1933; Baskin and Baskin 1985, 1986). Within the Great Lakes region only the alvars on the Napanee Plain and northwestern New York have a substantial amount of Red Cedar. Among the characteristic species of the cedar glades are *Scutellaria parvula*, *Sporobolus vaginiflorus* and *Trichostema brachiatum* (Baskin and Baskin 1975) which are also characteristic of the more northern alvars. Baskin and Baskin (1986) noted that Great Lakes region alvars have at least 30 species in common with with the southeastern cedar glades. Despite these similarities the cedar glades differ substantially in floristic composition from Great Lakes region alvars, especially with respect to their high numbers of endemics including such well known examples as Groundplum (*Astragalus tennesseensis*), Gattinger's Dalea (*Dalea gattingeri*), Alabama Larkspur (*Delphinium alabamicum*), *Leavenworthia* spp., Appendaged Lobelia (*Lobelia appendiculata* var. *gattingeri*), Gattinger's Goldenrod (*Solidago gattingeri*), Short's Goldenrod (*Solidago shortii*), Buckroot (*Pediomelum subacaule*) and Eggleston's Violet (*Viola egglestonii*) (Baskin and Baskin 1986, 1988). The endemic elements suggest that the sites have been available for speciation for a long period of time (Baskin and Baskin 1986). This is in contrast to the more northern alvars where endemics are fewer and are probably periglacial relicts that colonized their present sites as these sites were uncovered by melting of the Wisconsin ice sheet approximately 10 000 years ago. The absence of most of the southern cedar glade endemics from the Great Lakes region alvars (*see* Baskin and Baskin (1986) for exceptions) may be due to their absence from the ice front and the northern *Picea* parkland during the full glacial period (see below under "Phytogeography and Origin").

Elsewhere in eastern North America, limestone rock barrens similar to alvars exist in areas to the north of the Great Lakes, particularly in the Gulf of St. Lawrence region. In these places, however, they differ floristically in having a more prevalent boreal and arctic species composition. The limestone barrens of north coastal Newfoundland for example have Dryas (*Dryas integrifolia*) and Opposite-leaved Saxifrage (*Saxifraga oppositifolia*). An important factor at these sites in addition to the substrate is cool onshore wind. Periodic drought is a less important factor than in Great Lakes region alvars. Alvar-like sites in Manitoba are currently under study.

Biodiversity

The first demonstration of variation in floristic diversity between alvar regions in the Great Lakes area was that of Catling et al. (1975) who found that the Manitoulin and Napanee Plain alvars had a higher diversity than Carden Plain, Bruce Peninsula and Smiths Falls. More recent and extensive data provide additional support for this conclusion (Appendix 2). The western Lake Erie alvars also have a relatively high diversity.

Belcher et al. (1992) showed that species richness within alvar sites was curvilinearly related to biomass and soil depth. Richness increased with soil depth and biomass above zero, but beyond a certain level of biomass and soil depth where shoot and root competition were significant factors, it declined and dominance of one or a few species was characteristic.

Introduced Species

Since the alvar sites examined were chosen on the basis of dominance of native vegetation, introduced plants are not a major feature, but are nevertheless present at all sites. In some cases, and especially in the case of of shrubs, there appears to be a negative influence on the native alvar flora. On the Napanee and Smiths Falls Plains, the encroachment of alien shrubs [e.g., Tartarian Honeysuckle (*Lonicera tatarica*), Lilac (*Syringa vulgaris*), Glossy Buckthorn (*Rhamnus frangula*) and especially Common Buckthorn (*Rhamnus cathartica*)] has reduced native herbaceous flora. The most frequent introduced herbs were Pale Alyssum (*Alyssum alyssoides*), Thyme-leaved Sandwort (*Arenaria serpyllifolia*), Smooth Brome Grass (*Bromus inermus*), Shepherd's-purse (*Capsella bursa-pastoris*), Mouse-eared Chickweed (*Cerastium fontanum*), Ox-eye Daisy (*Chrysanthemum leucanthemum*), King Devil Hawkweed (*Hieracium piloselloides*), Queen Anne's Lace (*Daucus carota*), Viper's-bugloss (*Echium vul-

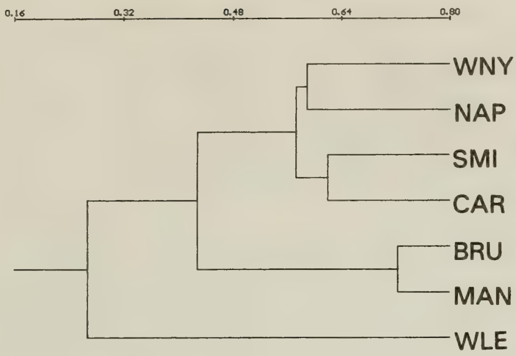

FIGURE 8. Relationships among seven regional alvar floras protrayed by a UPGMA clustering derived from a matrix of Jaccard's coefficients from species presence/absence data. The cophenetic correlation (r) = 0.97.

gare), Common St. John's-wort (*Hypericum perforatum*), Field Pepper-grass (*Lepidium campestre*), Black Medic (*Medicago lupulina*), Timothy (*Phleum pratense*), Canada Blue Grass (*Poa compressa*) (possibly native), Prostrate Knotweed (*Polygonum arenastrum*), *Portulaca oleracea, Potentilla argentea, Potentilla recta,* Dogmint (*Satureja vulgaris*), Bladder Campion (*Silene vulgaris*), Meadow Goat's-beard (*Tragopogon pratensis*), and Bird Vetch (*Vicia cracca*). Among the unusual introduced species are *Polycnemum arvense* and *Taraxacum palustre* on the Smiths Falls Plain (Brunton 1986*; Oldham et al. 1992).

Phytogeography and Origin

The alvar floras of seven regions are apparent as three major groups in both the phenogram (Figure 8) and the PCO plot (Figure 9). These are: (1) the western Lake Erie alvars with a proportionally high component of species occurring to the south, but a relatively small proportion of those occurring to the north (Figure 10), (2) the alvars of the Bruce Peninsula and Manitoulin Island with a high proportion of northern and endemic species; and (3) the alvars of central Ontario, eastern Ontario, and northern New York with a moderate representation of species occurring also to the north, but with a major proportion of southern species (Figure 10). A classification of these seven regions based on phytogeographic affinity of their alvar floras gave a similar result.

1. Southern elements

The origin of the flora in alvars may have differed between each of the three major groups. For example the western Lake Erie alvars, with the strong dominance of southern and western species (Figure 10), may have been colonized during the xerothermic period (5000 BP, Deevey and Flint 1957). Among the southern species present here at the northern limit of their ranges are Nodding Onion (*Allium cernuum*), *Aster shortii, Blephilia ciliata*, Boltonia (*Boltonia asteroides*), Wild Hyacinth (*Camassia*

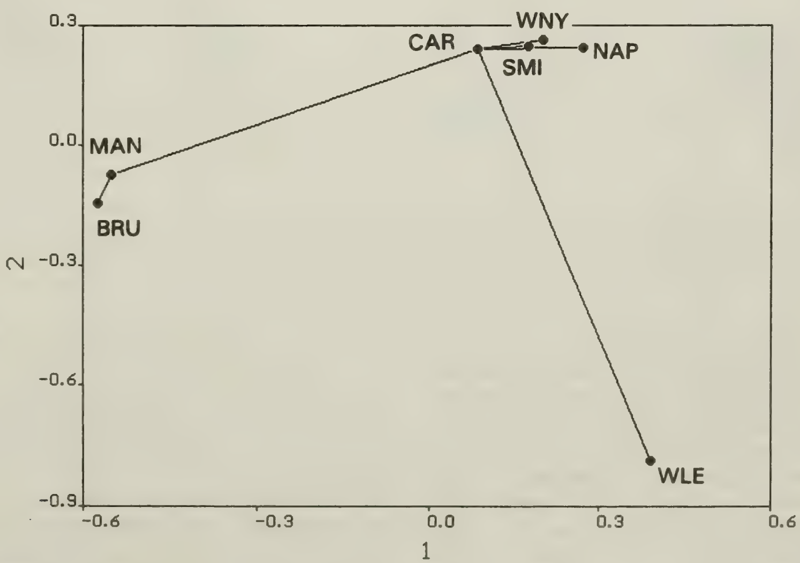

FIGURE 9. Relationships among seven regional alvar floras portrayed by a principal coordinate analysis based on a matrix of Jaccard's coefficients from species presence/ absence data. The first axis accounted for 28.1% of variation while the second included 26.8%.

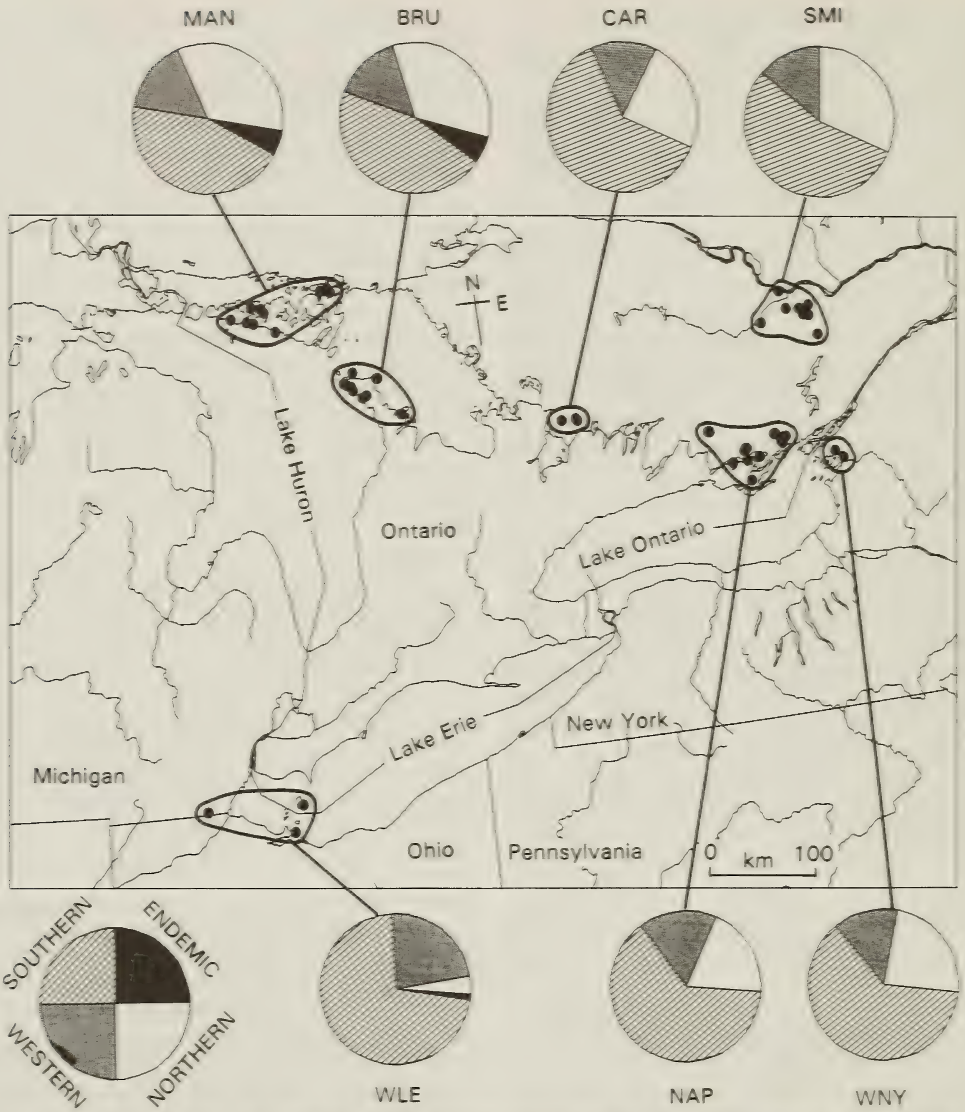

FIGURE 10. Map showing 59 study sites and pie diagrams illustrating the relative proportion (%) of species of various floristic affinity present on alvars in seven alvar regions of eastern Great Lakes area.

scilloides), *Carex leavenworthii*, *Hedyotis nigricans*, *Leucospora multifida*, Miami Mist (*Phacelia purshii*), Hairy-jointed Meadow Parsnip (*Thaspium barbinode*), Purple Meadow Parsnip (*Thaspium trifoliatum*), *Tomanthera auriculata*, and Tall Cornsalad (*Valerianella umbilicata*). Outside of western Lake Erie, the most well-developed southern element is on the alvars of the Napanee Plain where *Carex juniperorum*, Dwarf Hackberry (*Celtis tenuifolia*), Yellow Stargrass (*Hypoxis hirsuta*) and *Draba reptans* reach their northern limits. The majority of the provincially rare species in Ontario alvars are southern species at or near to their northern limits (Appendix 2).

2. Endemics and periglacial grasslands

The endemic element of alvars (see Appendix 2) is largely confined to the alvars near the shores of the upper Great Lakes (primarily the alvars of the Bruce Peninsula and Manitoulin Island) (Figure 10). The one exception is the Lakeside Plains on the Marblehead Peninsula of western Lake Erie where the Lakeside Daisy (*Hymenoxys herbacea*) is prevalent (see cover). The endemics on Bruce and

Manitoulin are part of a large group of plants including western, cordilleran and boreal disjuncts, which in the Great Lakes region are largely confined to the Great Lakes shores (Guire and Voss 1963; Marquis and Voss 1981). The endemic Dwarf Lake Iris (*Iris lacustris*), which probably came from the south, is a notable exception to this relationship with the north and the west.

In their association with open, disturbed habitats and a more-or-less disjunct boreal and western (or cordilleran) floristic element, the endemics of the upper Great Lakes are similar to the endemics of the Gulf of St. Lawrence (Scoggan 1950; Drury 1969; Catling and Cayouette 1994). This similarity suggests the same probable origin; i.e. they are probable remnants of a tundra and *Picea* Parkland flora that existed near the continental ice front in open, cool habitats that resulted from erosion and deposition by ice and water. These species followed the melting continental ice back to the regions of the upper Great Lakes and Gulf of St. Lawrence, and were able to survive in these areas due to the cool, moderate climate and availability of open habitats, such as shorelines, cliffs, and rocky barrens. As the continental ice sheet receded further to the north, a colder and more extreme climate was encountered and the extensive blanket of boreal forest developed leaving few open habitats. Thus not all of the flora of the open, ice front habitats was able to survive in, or even to migrate to, the current arctic tundra, and some species were left as relicts in isolated patches of suitable habitat around the Gulf and the upper Great Lakes (e.g., the largely cordilleran Alaska Orchid (*Piperia unalascensis*), Figure 11).

Some endemics, such as *Hymenoxys herbacea*, whose closest relatives and centre of diversity are in the west, probably moved in along the periglacial "sidewalk" from the west (e.g., Marie-Victorin 1938; Catling and Cayouette 1994). The concept of continuous grasslands with *Sporobolus heterolepis* along the Wisconsin ice front and in the *Picea* Parkland is supported by the present isolated occurrences of western prairie leafhoppers with flightless females, such as *Hecalus heterolepis* and *Aflexia rubranura*, on alvars of the upper Great Lakes and even the Ottawa valley (Hamilton 1994, 1995*). Presumably the presence of these flightless insects in currently isolated patches of alvar grassland can only be explained by the continuity of the vegetation until 9000 years ago, followed by fragmentation as forest zones moved northward.

With both endemics and a mixture of arctic, xeric and temperate elements, the periglacial community may not have a modern analogue (Brunnschweiler 1962; Whitehead 1973; Webb 1987; Wright 1987). The mixture is well illustrated by a remarkable mammal fauna consisting of what are today arctic species, such as Arctic Lemmings (*Dicrostonyx* spp.) and Arctic Ground Squirrels (*Citellus parryi*), occurring with species currently associated with prairie such as Thirteenline Ground Squirrel (*Citellus tridecemlineatus*) and Prairie Voles (*Microtus ochrogaster*), as well as Eastern Chipmunks (*Tamias striatus*), currently of the eastern deciduous, mixed and boreal forests (Wright 1987). If not a complete analogue, the alvars and dunes along the shores of the upper Great Lakes (Figure 7) and the sea cliffs and summits of the Gulf of St. Lawrence (Catling and Cayouette 1994), are at least of great interest in their apparent similarity to the periglacial environment.

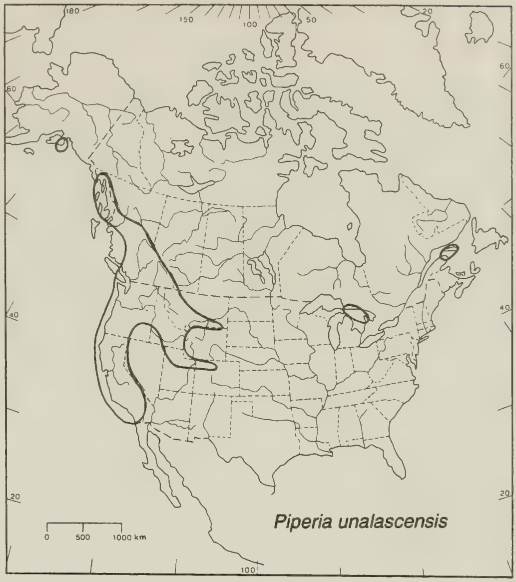

FIGURE 11. Distribution of *Piperia unalascensis* in North America based on references to distribution in regional floristic manuals and specimens at CAN and DAO.

3. Boreal species

The alvars of the Bruce Peninsula, Manitoulin Island, and northern Michigan in particular include arctic and/or boreal and/or cordilleran elements (Figure 10) at the more-or-less disjunct southern limits of their range such as *Allium schoenoprasum*, Red Anemone (*Anemone multifida*), *Carex capillaris, Carex scirpoidea, Piperia unalascensis, Poa alpina, Poa glaucantha, Primula mistassinica,* Tussock Bulrush (*Scirpus caespitosus*) and *Trisetum spicatum*. Of these *Carex scirpoidea* and *Scirpus caespitosus* are locally dominant, and the cordilleran disjunct, *Piperia unalascensis* (Figure 11) is frequent. Alpine Hedysarum (*Hedysarum alpinum*) has been reported from an alvar along the Escanaba River in northern Michigan (Chapman 1986). *Carex castanea, Carex richardsonii* and *Picea glauca* are boreal elements characteristic of many alvars south to and including those on the Napanee Plain where

FIGURE 12. Distribution of *Geum triflorum* in North America based on references to distribution in regional floristic manuals and specimens at CAN and DAO.

FIGURE 13. Broomrape (*Orobanche fasciculata*) on the Cloche Island Alvar, where it is parasitic on *Artemesia campestris*. The abundance of the host has been reduced by heavy grazing of beef cattle and currently the Ontario population consists of 40 clumps like the one illustrated, these confined to an area where cattle are absent.

they represent a particularly interesting contrast to the southern elements (e.g., *Carex oligocarpa*, *Carya ovata*, White Trout-lily (*Erythronium albidum*), Twin-leaf (*Jeffersonia diphylla*), *Quercus muehlenbergii*) of the nearby deciduous forests. The eastern Ontario and western New York alvars may be partial relicts of ice-front vegetation, but are evidently also partially a consequence of recent invasion of southern and western species of open ground.

4. Western species

Although there may be differences between alvars in different regions with respect to the origin of their floras, the one thing that all sites have in common is a modest but conspicuous relationship with regions to the west (Figure 10). Among the prominent species that are widespread in the west, extending narrowly eastward into the Great Lakes region on alvars (and sometimes also prairies) are: *Astragalus neglectus, Bouteloua curtipendula, Carex crawei, Carex richardsonii, Cirsium hillii, Geum triflorum* (Figure 12), *Draba reptans, Liatris cylindracea, Sporobolus heterolepis* and *Trichostema brachiata*. Elements of midwestern affinity include such characteristic species as *Eleocharis compressa* and *Ranunculus fascicularis*. The provincially rare species on alvars (Appendix 2) include some species that are largely confined to alvars in the eastern Great Lakes portion of their ranges (e.g., western species such as *Bouteloua curtipendula, Sporobolus heterolepis, Myosurus minimus*). One of the rarest western disjuncts in Ontario, Broomrape (*Orobanche fasciculata*) (Figure 13), occurs on the alvars of Cloche Island in the North Channel of Lake Huron. Since the Wisconsin ice front biota included both arctic/boreal and prairie elements (Wright, Jr. 1987 and see above), prairie species, including dominants such as *Sporobolus heterolepis* and *Schizachyrium scoparium,* may represent persisting relicts of the ice front flora. Although the Bruce Peninsula and Manitoulin Island were under water in early postglacial times, they were probably connected and more extensive by 9500 years ago (Lewis and Anderson 1989). At this time, species occupying the cool environment on higher ground on the east side of Lake Algonquin could have invaded the Bruce-Manitoulin areas. At approximately this time, and for more than 1000 years, the precursor of Lake Huron (Lake Chippewa-Hough) was much smaller than Lake Huron and the Bruce-Manitoulin area was continuous with dry land extending into the midwest. Thus there was also apparently an opportunity for eastward migration of prairie species during a milder early postglacial climate (see above, also Marie-Victorin 1938 and Hamilton 1994). However, a postglacial western origin during the warmer and drier xerothermic period (Deevey and Flint 1957) is

also a possibility for the origin of the western plant species as suggested by various authors (e.g., Catling et al. 1975; Stephenson 1983; Cusick 1991).

Restricted Fauna

Just as alvars contain some rare and disjunct plants with southern, western and northern affinities, there are also many similar, isolated and disjunct occurrences of fauna. A comprehensive analysis of them is beyond the scope of the present work, but we briefly allude to some of the more important examples that have come to our attention. Brunton (1986*) provided a useful example including a relatively extensive analysis of moths on the Burnt Lands Alvar complex near Ottawa which included several rare, restricted or disjunct species, as well as some newly discovered species of Owlet Moths in the genus *Anomogyna*.

The Garita Skipper butterfly (*Oarisma garita*) occurs on the Cloche Island alvars 1040 km (*ca.* 650 miles) west of the eastern edge of its more or less continuous range in the prairie provinces and Rocky Mountains (Catling 1977). The Olive Hairstreak (*Mitoura gryneus*) is a very localized butterfly in Ontario with the majority of its best Ontario sites on the Red Cedar savanna on the Napanee Plain. Other butterflies of restricted occurrence in Ontario that are present on alvars include the Hoary Elfin (*Incizalia polios*), the larvae of which feed on Bearberry (*Arctostaphylos uva-ursi*), and the Mottled Duskywing (*Erynnis martialis*), the larvae of which feed on New Jersey Tea (*Ceanothus* spp.).

Among the western insects that have been found on the Burnt Lands Alvar near Ottawa, the ground beetle *Chlaenius purpuricollis* is very rare and restricted in eastern Canada and has never been found in man-made habitats (H. Goulet, personal communication). Another example of a western prairie insect disjunct in the alvars of the Ottawa valley and near Marmora, is the sawfly, *Blennogeneris spissipes* (H. Goulet, personal communication). Some flightless leafhoppers disjunct and isolated on Ontario alvars are species otherwise associated with the western prairies, and populations surviving on alvars are thought to be remnants of more continuous populations that once existed on essentially continuous periglacial grasslands of 9000 years ago (Hamilton 1994, 1995*). Among the insects there are probably many examples of rare, restricted, disjunct, and entirely new species yet to be discovered in alvar habitats.

Despite the periodic dryness of the habitat, some unusual molluscs exist on alvars. On the Burnt Lands near Ottawa, species in the genera *Novasaxinea* and *Neohelix* have arctic and prairie relationships respectively. Other species are southern, and some new species have been recently discovered (W. Grimm, personal communication). The co-occurrence of different biogeographic elements in mollusc fauna is consistent with the periglacial relict hypothesis derived from plant and leafhopper distributions.

Several rare and restricted birds are also associated with alvars in Ontario. Both pristine and secondary alvars are the last major strongholds of the Loggerhead Shrike (*Lanius ludovicianus*) in southern Ontario (Cadman 1985*, 1987, 1990*; Chabot 1994*), a species which is listed under under the provincial Endangered Species Act. The breeding distribution of this bird corresponds very closely with geographic occurrence of alvar landscape (cf. Cadman 1987 and Catling 1994). It is believed that Loggerhead Shrikes moved into Ontario in the late 1800s as the land was cleared. However, the open alvar landscapes that they have receded to have probably been available for thousands of years and it seems possible that they were present in this restricted region of the province in low numbers long before they became widespread in agricultural landscapes. The same may be true of Clay-colored Sparrows (*Spizella pallida*). Alvars are probably the most stable habitats occupied by these birds in Ontario. The Prairie Sharp-tailed Grouse (*Tympanuchus phasianellus campestris*), which inhabits alvars on Manitoulin Island, is also regarded as a possible introduction (Lumsden 1987), although as in the case of the preceding species it is just as likely on biogeographic grounds that it was always present. Despite several attempts to introduce Prairie Sharp-tailed Grouse to other parts of southern Ontario, the only successes have been in the alvar landscapes of the Carden, Napanee and Smiths Falls limestone plains (Lumsden 1987). Another example is provided by Upland Sandpipers (*Bartramia longicauda*) which are characteristic of the alvar grasslands on the Carden Plain (personal observation) and in New York State (Reschke 1990). In presettlement times alvars may have been the only habitat in Ontario occuppied by these birds which now extensively use agricultural landscapes (Eagles 1987).

The Stone Road alvar on Pelee Island is the habitat of an endangered snake, the Blue Racer (*Coluber constrictor foxi*), which however is not confined to alvar habitats, even on the island. A number of other animals fall into this category of significant species using alvar habitat but not confined to it. Other examples at Stone Road include the Giant Swallowtail Butterfly (*Papilio cresphontes*) and various Carolinian bird species.

Significance of Alvars

Significant communities, flora, fauna and germplasm

Apart from the globally imperiled and threatened communities (see Introduction), alvars contain various endangered, threatened, endemic, rare and restricted animals and plants (see above, Appendix 2 and under "Some Protected Sites"). Forty-three plant

species regarded as rare in Ontario occur on alvars (Appendix 2).

All of the biodiversity in alvars is potentially useful, but some plants in particular are of importance in future improvement and diversification of Canadian crops. Cultivated crop relatives such as Wild Strawberry (*Fragaria virginiana*), Saskatoons (*Amelanchier alnifolia* and other species), Currants (*Ribes* spp.), Wild Onions (*Allium cernuum* and *A. schoenoprasum*), Cherries (*Prunus pumila* var. *depressa*, *Prunus virginiana*) and Plums (*Prunus americana*, *P. nigra*) are all characteristic plants of alvars. It is quite possible that the plants of these crop relatives that are found on alvars are genetically different from the same species growing in other less extreme environments, through adaptation to periodic drought for example. Protection of alvar habitats provides *in situ* protection for these and other potentially valuable crop relatives.

Research

Alvars are clearly important habitats to the understanding of past vegetation and the impacts of climatic change on vegetation. Like other dry habitats, they are particularly sensitive to drought and thus provide situations where effects of environmental changes involving drought could be readily monitored. Alvars have been under-utilized in testing and elucidating ecological principles and they contain material important for continuing research in the fields of evolution, taxonomy and biogeography. The fact that alvars require more study is punctuated by the discovery of new species of insects (e.g., Brunton 1986*), snails (F. W. Grimm, personal communication) and a new species of plant (Catling et al. 1993).

Ecotourism

The alvars of the Marblehead Peninsula (see cover) were once a major tourist attraction bringing bus loads of people from many hundreds of miles away to view the exceptional displays of wildflowers. It is difficult to assess the impact of their destruction on the local economy. Currently sites on the Bruce Peninsula with Wood Lily (*Lilium philadelphicum*), *Potentilla fruticosa, Coreopsis lanceolata* and Indian Paintbrush (*Castilleja coccinea*) are very popular with naturalists and photographers. The experience leading to the creation of the Lakeside Daisy Preserve in Ohio (see below) demonstrated clearly that alvar flora may be highly valued by local residents and the general public.

Protection of Alvars

Some protected sites

One of the abandoned quarries on the Marblehead Peninsula of Ohio was established in 1988 as a nature reserve to protect the Lakeside Daisy (*Hymenoxys herbacea*) which was was a dominant plant on the Lakeside Plains (see cover). The Lakeside Daisy is officially listed as threatened in the United States (DeMauro 1990*, 1993; Cusick 1991). Attempts to protect its last U. S. station on the Marblehead Peninsula began with Ohio botanist Mrs. Ruth Fiscus, who had been featuring the Lakeside Daisy in lectures and garden club field trips for many years. In early to mid-May during the 1940s people came from hundreds of miles away to see the spectacular display of thousands of golden blossoms extending for miles and all facing the same direction as they tracked the sun, along with an impressive display of flowering Redbud (*Cercis canadensis*). Much of the habitat was destroyed in the early 1950s, but plants peristed in isolated places and spread to some of the spent quarries (e.g., Williams 1963*). In 1981 the last natural site for Lakeside Daisy in Illinois was destroyed leaving only a salvaged group of self-incompatible plants that could not produce seed (DeMauro 1993). The Marblehead Peninsula then became the last natural population in the U.S. and the only one left outside of the Bruce Peninsula and Manitoulin Island in Ontario (DeMauro 1990*, 1993). Soon after, Ohio State University professor Ron Stuckey suggested to local resident Colleen Taylor that local support may be necessary to obtain adequate protection for the Lakeside Daisy. Taylor teamed up with Mrs. Fiscus and Ohio Department of Natural Resources biologists Guy Denny and Allison Cusick to educate residents and potentially concerned organizations. Taylor and Fiscus circulated petitions and obtained thousands of endorsements. The campaign began locally and eventually spread across the country. It was successful for many reasons, among which was the extent of their committment. Both ladies received the Ohio Conservation Achievement Award. Their work provides an outstanding example of successful protection of alvar flora in the Great Lakes region (Denny 1986*; Anonymous 1988; correspondence files in DAO herbarium). Additional information on the Lakeside Plains can be obtained in various papers cited by DeMauro (1990*). As part of the recovery plan, the Lakeside Daisy was recently introduced to some apparently appropriate habitats within Kelleys Island State Park, on one of the islands in western Lake Erie as well as in three Illinois Nature Preserves (DeMauro 1993).

The Stone Road Alvar on Pelee Island contains more rare species than any other alvar in Ontario (Duncan 1973; Campbell and Reznicek 1977; Jacques and Kirk 1985; Oldham 1983*, 1987; Oldham and Kamstra 1989*; Kirk 1994). Fortunately a large portion of the area was acquired for protection by the Federation of Ontario Naturalists in 1984 with a loan from the Ontario Heritage Foundation which was paid off through donations from the membership and matching government funds. Additional adjacent lands were later purchased by

the Essex Region Conservation Authority in 1989 (Federation of Ontario Naturalists 1993*). The Stone Road Alvar is one of the few sites where management options have been considered in some detail (Kirk 1994), but fire may be unnecessary on many alvars. Stone Road is an unusual site in having prairie, savanna and alvar vegetation.

Alvars are also protected within Bruce Peninsula National Park, particularly a fine site on Bears Rump Island (Morton and Venn 1987). Another alvar adequately protected in Ontario is the Misery Bay site on Manitoulin Island which is a Provincial Nature Reserve (Macdonald 1980*). A portion of the Burnt Lands Alvar near Ottawa is partially protected through the designation of Crown lands as "Conservation Reserve".

A detailed account of the protection of all protected alvars in the Great Lakes region is beyond the scope of the present review, but it may be noted that the Nature Conservancy has made some progress through the establishment of preserves in the Maxton Plains on Drummond Island, Michigan, as well as in the Limerick Cedars and Chaumont Barrens sites in New York. More information on these and other initiatives is available through the Nature Conservancy Field Offices.

Protection needs

When considering protection of significant community types, quality is always a concern. Alvars in the Great Lakes Region exhibit a range from low to high degree of disturbance, although some subjectivity is involved in defining this. Sites with a low to moderate amount of disturbance are those with a substantial component of native species and with a large number of native species characteristic of alvars (Catling 1994). During the course of this work, at least 60 sites were examined that are presently highly disturbed or have been severely disturbed in the past through heavy grazing, garbage deposition, removal of upper layers, etc. Many of the provincially rare plant species on alvars, such as *Orobanche fasciculata* (Figure 13), are totally absent from grazed sites. On the Smiths Falls and Napanee Plains, and in western Lake Erie and western New York, the percentage of habitat of reasonable quality remaining, based on diversity, characteristic species (Catling 1994), and limited occurrence of alien species, is very small relative to the original extent of alvar in these regions. Nutrient input and trampling by grazing livestock result in the replacement of native alvar species with an aggressive Eurasian flora (see above under "Introduced Species"), but quarry and residential development are also beginning to have a major impact.

Approximately 85% of alvar sites and more than 90% of the alvar landscape area in the Great Lakes region is in Ontario where only a small portion of the available habitat is adequately protected. In each of the adjacent United States a relatively large portion of the available habitats are protected, although in no case is the protected area sufficiently extensive. Many opportunities exist for restoration of badly degraded sites. Some alvars in Ontario are designated as ANSIs (Areas of Natural and Scientific Interest) and briefly described in various site district reports on file with the Ontario Ministry of Natural Resources. The ANSI system identifies significant features which are recommended for protection through municipal and township zoning. However, recommendations are not always promoted by the appropriate agencies or followed by municipal planning councils. One of the best examples of the limitations of the ANSI system in Ontario was the destruction of a significant portion of the Burnt Lands Alvar near Ottawa by a landowner who wanted the zoning changed to allow quarrying. Although the ANSI system has been very useful in documenting and priorizing sites for protection and has also in some cases lead to a degree of protective zoning, it is not by itself a sufficiently reliable method of protecting provincially and regionally significant sites.

An ecosystem approach to the protection of rare, threatened and endangered species has the obvious advantages of leading to the protection of an entire ecosystem in which a number of significant components reside. The relevant question relates to how much has to be protected to obtain adequate representivity (Belcher and Keddy 1992). A preliminary study of alvars in the eastern Great Lakes region based on the relationships among 55 sites indicated 8 major types that differed from one another to varying degrees (Catling and Catling, unpublished data). These eight types corresponded closely to the geographic regions employed here (Figure 10, Appendix 1), with one exception. The alvars of Manitoulin Island may be grouped into two kinds: those on the north coast (North Channel), and those on the south coast. The reasons for the differences are not absolutely clear but the softer limestone of the north shore, which is more prone to flaking and the development of parent material for soil, may provide part of the explanation. Drawing winds from a more extensive body of water instead of from both land and water, the south coast may also be cooler. There are few, if any sites, where all of the characteristic alvar plant species occur or even where there is good representation of all alvar associations. More often a particular site has one or two associations well developed and good populations of some of the rare species with other rare species sparse or absent. In many cases, it would be necessary to protect two or three sites within each of the eight regions in order to achieve adequate representation. In Ontario, for example, this would require the protection of approximately 24 sites. Currently less than one-quarter of this number are adequately protected. These

include Misery Bay on Manitoulin Island, a few sites in the newly established National Park on the Bruce Peninsula, Stone Road Alvar on Pelee Island in western Lake Erie, and a portion of the Burnt Lands near Ottawa. Some of the most impressive sites on the Napanee and Smiths Falls limestone plains have been either destroyed totally or partially over the past several years. Initially, threats were limited to quarrying and grazing; but recently, the extension of residential and recreational areas has become a major threat on the Napanee and Smiths Falls Plains. In some places the encroachment of alien shrubs such as *Rhamnus cathartica*, *Rhamnus frangula*, *Lonicera tatarica* and *Syringa vulgaris* have eliminated native alvar flora and resulted in a closing of the alvar savanna, but the extent to which this is due to past grazing and its effect on rare species has yet to be determined. Alvars are an important natural resource requiring both additional study and comprehensive planning for protection.

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APPENDIX 1. Moderate to high quality alvar sites documented with species composition data in the Great Lakes region and mapped in Figure 3. The latitude and longitude coordinates are approximate and rounded off to feet. The only sites mapped, but not listed here, are those along the Niagara River, Maitland River and on the Flamborough Plain near western Lake Ontario, for which precise data on primary locations are currently incomplete. Many shoreline alvars of the upper Great Lakes are not well documented and are also not listed here.

Northern Michigan
Alpena, 45°05′, 83°25′
Bass Cove, 45°56′, 83°32′
Escanaba River, 45°53′, 87°12′
Escanaba River, 45°53′, 87°07′
Escanaba River, 45°54′, 87°09′
Garden Peninsula, 45°40', 86°40′
Huron Bay, 45°57', 83°45'
Maxton Plains West, 46°05', 83°42'
Maxton Plains East, 46°04', 83°37'
Maxton Plains Middle, 46°04', 83°39'
Rogers City area, 45°25', 83°45'
Seaman's Point, 45°56', 83°41'
Seul Choix Point, 45°56', 85°55'
Thunder Bay Island, 45°02', 83°12'

Western Lake Erie
Michigan - Sterns Road, 41°45', 83°41'
Ohio - Lakeside Plains, 41°31' 82°43'
Ontario - Stone Road, 41°45', 82°37'

Western New York
Chaumont Barren, 45°05', 76°05'
Limerick Cedars, 44°03', 76°02'
Lucky Star, 44°07', 76°07'

Napanee Plain, Ontario
Howes Road, 44°18', 76°39'
Odessa North, 44°16', 76°43'
Odessa South, 44°15', 76°42'
Asseltine, 45°15', 76°43'
Camden East, 44°20', 76°47'
Camden South, 44°20', 76°46'
Camden West, 44°19', 76°60'
Gretna, 44°10', 76°59'
Point Anne, 44°09', 77°18'
Picton, 43°59', 77°07'
Solmesville, 44°09', 77°08'
Lonsdale, 44°15', 77°07'
Salmon River North, 44°14', 77°09'
Bend Bay West, 44°26', 77°32'
Bend Bay East, 44°26', 77°31'
Lonsdale Northwest, 44°15', 77°08'
Deseronto North, 44°12', 77°05'
Deseronto South, 44°11', 77°05'
Massasauga Point, 44° 08', 77°19'
Marmora, 44°29', 77°42'
Crowe Bridge, 44°23', 77°45'
Yarker, 44°22', 76°47'

Smiths Falls Plain, Ontario
Marathon, 45°20', 76°08'
Ramsay, 45°16', 76°11'
Clay Bank, 45°20', 76°24'
Burnt Lands, 45°15', 76°09'
Panmure, 45°19', 76°15'
Sneddon, 45°16', 76°13'
Braeside, 45°29', 76°27'

Bruce Peninsula, Ontario
Cape Croker, 44°55', 81°03'
Cabot Head North, 45°14', 81°17'
Cabot Head West, 45°14', 81°18'
Bears Rump Island, 45°18', 81°34'
Cape Hurd Road, 45°13', 81°41'
Hopkins Bay, 45°12', 81°38'
Dorcas Bay North, 45°11', 81°36'
Little Eagle Point, 45° 09', 81°35'
Dyer Bay Road, 45°06', 81°26'
Pine Tree Harbour, 45°05', 81°29'

Manitoulin Island, Ontario
Dominion Point, 45°42', 82°26'
Foxey Barren, 45°52', 82°33'
Rozels Bay, 45°54', 82°35'
Barrie Island, 45°55', 82°42'
Burnt Island Harbour, 45°50', 82°57'
Macs Bay, 45°47', 82°41'
Misery Bay, 45°43', 82°46'
Little Cloche Island, 45°59', 81°44'
Dreamers Rock, 46°00', 81°47'
McGregor Bay, 46°01', 81°46'
Lewis Lake, 46°00', 81°51'

Carden Plain, Ontario
Carden Plain 1, 44°38', 79°01'
Carden Plain 2, 44°39', 79°01'
Carden Plain 3, 44°40', 79°01'
Carden Plain 4, 44°40', 79°05'
Carden Plain 5, 44°40', 79°04'
Carden Plain 6, 44°41', 79°03'
Carden Plain 7, 44°40', 79°04'
Nogies Creek, 44°37', 78°29'

Vermont
Twin Bridges, 44°29', 73°11'
Button Bay State Park, 44°11', 73°21'

APPENDIX 2. Native vascular plant taxa recorded on alvars in seven alvar regions (illustrated in Figure 10) within the Great Lakes region. Bold face type indicates characteristic species; *i.e.*, found in more than 50% of the 63 sites (see Appendix 1) examined. Species restricted to alvars are not indicated here but are discussed in Catling (1994). The following symbols are utilized: P = rare in Ontario based generally on Argus and Keddy (1984), Argus and White (1982, 1983), Pryer and Argus (1987); r = restricted in Ontario (not of general occurrence throughout the southern part of the province); X = not known from Ontario; E = endemic to Great Lakes region. Authorities for scientific names and synonymy may be found in Morton and Venn (1987). WNY = northwestern New York. SMI = Smiths Falls Plain. NAP = Napanee Plain. CAR = Carden Plain. BRU = Bruce Peninsula. MAN = Manitoulin Island. WLE = Western Lake Erie. This list is incomplete for species of shoreline alvars which have not yet been inventoried in detail, and is not a complete list for the Great Lakes Region. .

STATUS	GENUS	SPECIES	WNY	SMI	NAP	CAR	BRU	MAN	WLE
	Abies	***balsamea***	x	x	x	x	x	x	–
	Agalinis	*tenuifolia*	x	x	x	x	x	–	x
	Agrostis	***scabra***	x	x	x	x	x	x	x
	Allium	*canadense*	–	–	x	–	–	–	–
P	*Allium*	*cernuum*	–	–	–	–	–	–	x
r	*Allium*	*schoenoprasum*[6]	–	–	x	–	–	x	–
	Ambrosia	***artemesiifolia***	x	x	x	x	x	x	–
	Amelanchier	***alnifolia compacta***	x	x	x	x	x	x	x
	Amelanchier	*sanguinea*	x	–	–	–	–	–	–
	Amelanchier	*stolonifera*	x	–	–	–	–	–	–
	Andropogon	*gerardii*	–	–	–	–	x	–	x
r	*Androsace*	*septentrionalis*	–	–	x	–	–	–	–
	Anemone	***cylindrica***	x	x	–	x	x	x	–
	Anemone	*multifida*	–	–	–	–	x	x	–
	Anemone	*virginiana*	x	–	–	–	–	–	x
	Antennaria	***neglecta***	x	x	x	x	x	x	x
	Antennaria	*neodioica*	–	–	–	–	–	–	x
	Antennaria	*plantaginifolia*	x	–	–	–	–	–	–
	Aquilegia	***canadensis***	x	x	x	x	x	x	–
	Arabis	*divaricarpa*	x	–	–	–	–	–	–
	Arabis	*drummondii*	–	–	x	–	–	x	–
	Arabis	*glabra*	x	–	–	–	–	–	–
	Arabis	***hirsuta***	x	x	x	x	x	x	x
r	*Arabis*	*lyrata*	–	–	–	–	x	x	–
r	***Arctostaphylos***	***uva-ursi***	x	x	x	x	x	x	–
	Artemesia	*campestris caudata*	–	–	–	–	–	x	–
	Asclepias	*incarnata*	–	–	–	–	x	x	–
	Asclepias	***syriaca***	x	x	x	x	x	x	x
r	*Asclepias*	*tuberosa*	–	–	–	–	–	–	x
r	*Asclepias*	*verticillata*	–	–	–	–	–	–	x
P	*Asclepias*	*viridiflora*	–	–	–	–	–	x	x
r	*Asplenium*	*trichomanes*	x	–	x	–	x	–	–
	Aster	cf. *praealtus*	–	–	–	–	–	–	x
	Aster	***cordifolius***	x	x	x	x	–	–	–
P	*Aster*	*dumosus*	–	–	–	–	–	–	x
	Aster	*laevis*	–	–	–	–	x	x	x
	Aster	*lanceolatus*	–	–	x	x	–	–	–
	Aster	*macrophyllus*	–	–	–	x	x	x	–
r	*Aster*	*oolentangiensis*	x	x	x	x	–	–	–
	Aster	*pilosus*	x	–	x	x	–	–	x
	Aster	***pringlei***	x	–	x	–	x	x	–
	Aster	*puniceus*	–	–	–	x	–	–	–
P	*Aster*	*shortii*	–	–	–	–	–	–	x
	Aster	*urophyllus*	x	–	x	–	–	–	–
r	*Astragalus*	*neglectus*	–	x	x	x	–	–	–
	Betula	***papyrifera***	x	–	–	x	x	x	–
P	*Blephilia*	*ciliata*	–	–	–	–	–	–	x
Xr	*Boltonia*	*asteroides*	–	–	–	–	–	–	x
	Botrychium	*multifidum*	–	x	–	–	–	–	–
P	*Bouteloua*	*curtipendula*	–	–	x	–	–	–	–
	Bromus	*ciliatus*	–	x	x	–	–	–	–
r	***Bromus***	***kalmii***	x	x	x	x	x	x	–
	Bromus	*pubescens*	–	x	x	x	–	–	–
r	*Cacalia*	*tuberosa*	–	–	–	–	x	–	–

APPENDIX 2. *Continued.*

STATUS	GENUS	SPECIES	WNY	SMI	NAP	CAR	BRU	MAN	WLE
	Calamagrostis	*canadensis*	–	–	–	–	x	x	–
	Calamagrostis	*stricta*	–	–	–	–	–	–	x
	Calamintha	*arkansana*	–	–	–	–	x	x	x
	Calystegia	***spithamea***	x	x	x	x	–	–	–
P	*Camassia*	*scilloides*	–	–	–	–	–	–	x
	Campanula	***rotundifolia***	x	x	x	x	x	x	–
	Cardamine	*parviflora*	–	–	–	x	–	x	x
	Carex	*argyrantha*	–	–	x	–	–	–	–
	Carex	*atherodes*	–	–	x	–	–	–	–
	Carex	*aurea*	x	x	x	x	x	x	x
	Carex	*backii*	x	x	x	x	–	–	–
P	*Carex*	*bicknellii*	–	–	x	–	–	–	x
	Carex	*blanda*	x	–	–	–	–	–	x
	Carex	*buxbaumii*	–	–	–	–	x	x	–
	Carex	*capillaris*	–	–	–	–	x	x	–
	Carex	*castanea*	x	x	x	x	x	x	–
r	*Carex*	*conoidea*	x	–	x	–	–	–	–
r	***Carex***	***crawei***	x	x	x	x	x	x	x
	Carex	***eburnea***	x	x	x	x	x	x	x
	Carex	***flava***	x	x	x	x	x	x	–
r	*Carex*	*foenea*	x	–	x	–	–	–	–
	Carex	*garberi*	–	–	–	–	x	x	x
	Carex	*granularis*	x	x	x	x	x	–	x
P	*Carex*	*juniperorum*	–	–	x	–	–	–	–
	Carex	***lanuginosa***	–	x	x	x	x	x	x
	Carex	*lasiocarpa*	–	–	–	–	x	–	–
P	*Carex*	*leavenworthii*	–	–	–	–	–	–	x
	Carex	*livida*	–	–	–	–	–	x	–
P	*Carex*	*meadii*	–	–	–	–	–	–	x
	Carex	*molesta*	x	x	x	x	x	x	x
	Carex	***pensylvanica***	x	x	x	x	–	–	x
r	***Carex***	***richardsonii***	x	x	x	x	x	x	–
	Carex	*rugosperma*	x	–	x	–	–	–	–
r	*Carex*	*sartwellii*	–	–	x	–	x	–	x
	Carex	*scirpoidea*	–	–	–	–	x	x	–
	Carex	*sterilis*	–	–	–	–	–	x	–
	Carex	***umbellata***	x	x	x	x	x	x	x
	Carex	*viridula*	–	–	–	–	x	x	x
r	*Castilleja*	*coccinea*	x	–	x	x	x	x	–
r	*Ceanothus*	*americanus*	–	–	x	x	–	–	–
r	*Ceanothus*	*herbaceus*	–	x	–	x	–	–	x
	Celastris	*scandens*	x	–	x	x	x	–	x
	Celtis	*occidentalis*	–	–	x	–	–	–	x
P	*Celtis*	*tenuifolia*	–	–	x	–	–	–	x
	Cerastium	***arvense***[2]	–	–	x	x	x	x	x
	Cerastium	*nutans*	–	–	x	x	–	–	–
	Cerastium	*velutinum (arvense)*	–	–	x	x	x	x	x
P	*Cercis*	*canadensis*	–	–	–	–	–	–	x
r	*Cirsium*	*discolor*	–	–	–	–	–	–	x
PE	*Cirsium*	*hillii*	–	–	–	–	x	x	–
	Cladium	*mariscoides*	–	–	–	–	x	x	–
	Clinopodium	*vulgare*	x	–	x	x	x	x	–
	Comandra	***umbellata***	x	x	–	x	x	x	x
r	*Coreopsis*	*lanceolata*	–	–	–	–	x	x	–
P	*Coreopsis*	*tripteris*	–	–	–	–	–	–	x
	Cornus	*drummondii*	–	–	–	–	–	–	x
	Cornus	***racemosa***	x	x	x	x	x	x	x
	Cornus	*stolonifera*	–	x	x	x	x	x	–
	Corydalis	*aurea*	x	–	x	–	–	–	–
r	*Corydalis*	*flavula*	–	–	–	–	–	–	x
	Corylus	*americana*	–	–	–	–	–	–	x
	Crataegus	sp.	–	–	–	–	x	–	–

APPENDIX 2. *Continued.*

STATUS	GENUS	SPECIES	WNY	SMI	NAP	CAR	BRU	MAN	WLE
	Crataegus	*crus-galli*	–	–	–	–	–	–	x
	Cuscuta	*pentagona*	–	–	–	–	–	–	x
r	*Cypripedium*	*arietinum*	–	x	–	–	x	x	–
	Cypripedium	*calceolus*	x	x	–	–	x	x	–
	Cystopteris	*fragilis*	x	–	x	x	x	x	–
	Danthonia	***spicata***	x	x	x	x	x	x	x
r	***Deschampsia***	***caespitosa***	x	–	x	x	x	x	–
	Deschampsia	*flexuosa*	x	–	–	–	–	x	–
	Desmodium	*canadense*	–	–	–	–	–	–	x
r	*Desmodium*	*paniculatum*	–	–	–	–	–	–	x
	Diervilla	*lonicera*	–	–	–	–	x	–	–
	Draba	*nemorosa*	–	x	–	x	–	x	–
	Draba	*reptans*	–	x	–	x	–	x	–
	Dracocephalum	*parviflorum*	x	–	x	–	–	–	–
	Dryopteris	*marginalis*	x	–	x	x	x	x	–
r	***Eleocharis***	***compressa***	x	–	x	x	x	x	x
	Eleocharis	*elliptica*	–	x	–	x	x	x	–
	Eleocharis	*erythropoda*	–	x	x	x	–	–	–
	Eleocharis	*obtusa*	–	–	x	x	–	–	–
	Elymus	***trachycaulus***	x	x	x	x	–	x	–
	Epilobium	***coloratum***	x	x	x	x	x	x	–
r	*Epilobium*	*hornemannii*[5]	x	–	–	–	–	–	–
	Epilobium	*leptophyllum*	–	x	x	–	–	–	–
	Equisetum	*hyemale*	–	–	–	–	–	–	x
	Equisetum	*variegatum*	–	–	–	–	x	x	–
	Eragrostis	*spectabilis*	–	–	–	–	–	–	x
	Erigeron	*philadelphicus*	x	x	x	x	x	x	x
PE	*Erigeron*	*phil. provancheri*[4]	–	–	–	–	x	–	–
	Erigeron	*strigosus*	x	x	x	x	x	x	x
	Eupatorium	*altissimum*	–	–	–	–	–	–	x
P	*Euonymus*	*atropurpureus*	–	–	–	–	–	–	x
	Euphorbia	*commutata*	–	–	x	–	–	–	–
	Festuca	*saximontana*	–	–	–	x	x	x	–
	Fragaria	***virginiana***	x	x	x	x	x	x	x
	Fraxinus	*americana*	–	–	x	–	–	x	–
	Fraxinus	*pennsylvanica*	–	–	–	–	x	–	x
P	*Fraxinus*	*quadrangulata*	–	–	–	–	–	–	x
	Galium	*boreale*	–	–	–	–	–	–	x
	Gentianella	*crinita*	–	x	–	x	–	–	–
r	***Geranium***	***bicknellii***	–	x	x	x	x	x	–
r	***Geranium***	***carolinianum***	x	–	x	x	x	x	x
r	***Geum***	***triflorum***	x	–	x	x	–	x	–
	Glyceria	***striata***	x	x	x	x	x	x	x
	Gratiola	*neglecta*	–	–	x	x	–	–	–
P	*Gymnocarpium*	*robertianum*	–	–	–	–	x	–	–
	Hedeoma	***hispida***	x	x	x	x	–	x	–
	Hedeoma	*pulegioides*	–	–	x	x	x	x	x
	Hedyotis	*longifolia*	x	–	x	x	x	x	–
X	*Hedyotis*	*nigricans*	–	–	–	–	–	–	x
	Helianthus	*divaricatus*	–	–	–	x	–	–	x
P	*Heuchera*	*americana*	–	–	–	–	–	–	x
	Hierchloe	*odorata*	–	–	–	–	–	x	–
PE	*Hymenoxys*	*herbacea*	–	–	–	–	x	x	x
E	*Hypericum*	*kalmianum*	–	–	–	–	x	x	–
r	*Hypoxis*	*hirsuta*	–	–	x	–	–	–	–
PE	*Iris*	*lacustris*	–	–	–	–	x	–	–
	Iris	*versicolor*	–	–	–	–	x	x	–
	Juncus	*balticus*	–	–	–	–	x	x	–
	Juncus	*bufonius*	–	–	–	–	–	–	x
	Juncus	*dudleyi*	x	x	x	x	x	x	x
P	*Juncus*	*secundus*	x	–	x	x	–	–	–
	Juncus	*tenuis*	–	x	x	–	–	–	–

APPENDIX 2. *Continued.*

STATUS	GENUS	SPECIES	WNY	SMI	NAP	CAR	BRU	MAN	WLE
	Juncus	*torreyi*	–	–	–	–	–	–	x
	Juniperus	***communis***	x	x	x	x	x	x	x
	Juniperus	*horizontalis*	–	–	–	–	x	x	–
	Juniperus	*virginiana*	x	x	x	–	–	–	x
	Lactuca	*canadensis*	–	–	–	–	–	x	–
P	*Lactuca*	*floridana*	–	–	–	–	–	–	x
	Larix	*laricina*	–	–	–	–	x	x	–
	Lepidium	***densiflorum***	x	x	x	x	x	x	x
	Lepidium	*virginicum*	–	x	x	x	x	x	–
r	*Lespedeza*	*intermedia*	–	–	–	–	–	–	x
r	*Liatris*	*cylindrica*	–	–	–	–	–	x	–
P	*Liatris*	*spicata*	–	–	–	–	–	–	x
r	***Lilium***	***philadelphicum***	x	x	x	x	x	x	–
	Linnaea	*borealis*	x	–	–	–	x	x	–
r	*Linum*	*sulcatum*	–	–	–	–	–	x	–
	Lobelia	*spicata*	–	–	–	x	x	–	x
	Lonicera	***dioica***	x	x	x	x	x	x	–
	Lonicera	*hirsuta*	–	–	–	x	–	–	–
	Maianthemum	*canadense*	x	–	–	x	–	x	–
	Melampyrum	*lineare*	x	–	–	x	x	x	–
	Minuartia	***michauxii***	x	x	x	x	x	x	x
	Monarda	*fistulosa*	x	–	x	x	–	–	x
	Muhlenbergia	***glomerata***	x	x	x	x	x	x	–
	Muhlenbergia	*mexicana*	x	x	x	x	–	–	–
P	*Myosurus*	*minimus*	–	–	x	–	–	–	–
	Myosotis	*verna*	x	–	x	–	–	x	x
	Oenothera	*perennis*	–	–	x	x	–	–	–
	Oryzopsis	***asperifolia***	x	x	x	x	x	x	–
	Oryzopsis	*pungens*	–	–	–	–	x	x	–
	Panicum	***flexile***	x	x	x	x	–	–	x
	Panicum	***implicatum***	x	x	x	x	x	x	x
r	*Panicum*	*lindheimeri*	–	–	–	–	x	x	–
	Panicum	*linearifolium*	x	–	x	x	–	–	–
r	*Panicum*	*oligosanthes*	–	–	–	–	–	–	x
	Panicum	***philadelphicum***	x	x	x	x	–	–	x
	Panicum	*virgatum*	–	–	–	–	x	x	x
P	*Pellaea*	*atropurpurea*	–	–	–	–	x	x	–
	Penstemom	***hirsutus***	x	x	x	x	–	–	x
P	*Phacelia*	*purshii*	–	–	–	–	–	–	x
	Physocarpus	*opulifolius*	–	–	–	x	x	x	–
	Picea	***glauca***	x	x	x	x	x	x	–
	Pinus	*banksiana*	–	x	–	–	x	x	–
	Pinus	*resinosa*	–	x	–	x	–	x	–
	Pinus	***strobus***	x	x	x	x	–	x	–
r	*Piperia*	*unalascensis*	–	–	–	–	x	x	–
r	*Poa*	*alpina*	–	–	–	–	x	x	–
r	*Poa*	*canbyi*	–	–	–	–	x	x	–
	Poa	***compressa***	x	x	x	x	x	x	x
r	*Poa*	*glaucantha*	–	–	–	–	x	x	–
	Poa	***pratensis***	x	x	x	x	x	x	x
	Polygala	***senega***	x	x	x	x	x	x	x
	Polygonum	*buxiforme*	–	–	x	–	–	–	–
r	*Polygonum*	*douglasii*	–	–	–	x	–	x	–
	Polygonum	*neglectum*	–	–	x	–	–	–	–
	Polygonum	*punctatum*	–	–	x	–	–	–	–
	Polypodium	*virginianum*	x	–	–	–	–	–	–
	Populus	*balsamifera*	x	x	–	x	–	x	–
	Populus	*deltoides*	–	–	–	–	–	–	x
	Populus	***tremuloides***	x	x	x	x	x	x	–
	Portulaca	***oleracea***	–	x	x	x	–	–	–
r	***Potentilla***	***arguta***	x	x	x	x	x	x	x
	Potentilla	*canadensis*	–	–	x	–	–	–	–

APPENDIX 2. *Continued.*

STATUS	GENUS	SPECIES	WNY	SMI	NAP	CAR	BRU	MAN	WLE
r	*Potentilla*	*fruticosa*	–	–	–	x	x	x	x
	Potentilla	***norvegica***	x	x	x	x	–	x	–
	Potentilla	*simplex*	–	–	x	x	–	x	x
r	*Prenanthes*	*racemosa*	–	–	–	–	x	–	–
r	*Primula*	*mistassinica*	–	–	–	–	–	x	–
	Prunella	***vulgaris*** s. l.	x	x	x	x	x	x	x
	Prunus	*americana*	–	–	x	x	–	–	–
	Prunus	*nigra*	–	–	x	x	–	–	–
	Prunus	*pumila depressa*	–	–	–	–	x	x	–
	Prunus	***virginiana***	x	x	x	x	x	x	x
P	*Ptelea*	*trifoliata*	–	–	–	–	–	–	x
	Pteridium	***aquilinum***	x	–	–	x	x	x	–
r	*Pycnanthemum*	*flexuosum*	–	–	–	–	–	–	x
	Pycnanthemum	*virginianum*	–	–	x	–	–	–	x
	Quercus	***macrocarpa***	x	x	x	x	–	x	x
r	*Quercus*	*muehlenbergii*	–	–	–	–	–	–	x
	Quercus	*rubra*	–	–	–	–	x	x	–
r	***Ranunculus***	***fascicularis***	x	x	x	x	–	x	x
	Ranunculus	*sceleratus*	–	–	–	x	–	–	x
P	*Ratibida*	*pinnata*	–	–	–	–	–	–	x
	Rhamnus	*alnifolia*	–	–	–	–	x	x	–
r	***Rhus***	***aromatica***	x	–	x	x	x	x	x
P	*Rhus*	*copallina*	–	–	–	–	–	–	x
	Rhus	*glabra*	–	–	x	–	–	–	x
	Rhus	***typhina***	x	x	x	x	–	x	x
	Ribes	*hirtellum*	–	x	–	–	–	–	–
	Rorippa	*palustris*	–	–	x	–	–	–	x
	Rosa	*acicularis*	–	x	–	x	–	–	x
	Rosa	***blanda***	x	x	x	x	x	x	x
r	*Rosa*	*carolina*	–	–	–	–	–	–	x
r	*Rosa*	*setigera*	–	–	–	–	–	–	x
	Rubus	*flagellaris*	–	–	–	x	–	–	x
	Rudbeckia	*hirta*	–	x	–	–	–	–	x
	Rudbeckia	*laciniata*	–	–	–	–	–	–	x
	Sarracenia	*purpurea*	–	–	–	–	x	–	–
	Saxifraga	***virginiensis***	x	x	x	x	x	x	–
	Schizachne	***purpurascens***	–	–	x	x	–	x	–
	Schizachyrium	*scoparium*	x	–	x	x	x	x	x
	Scirpus	*atrovirens*	x	x	–	–	–	–	–
r	*Scirpus*	*caespitosus*	–	–	–	–	x	x	–
	Scirpus	*pendulus*	–	x	–	–	–	–	x
r	***Scutellaria***	***parvula***	x	x	x	x	x	x	x
	Selaginella	***rupestris***	x	x	x	x	–	x	–
	Senecio	***pauperculus***	x	x	x	x	x	x	x
	Senecio	*plattensis*	–	–	–	–	–	–	x
	Shepherdia	***canadensis***	x	x	x	x	x	x	–
	Silene	***antirrhina***	x	x	x	x	x	x	x
P	*Silphium*	*terebinthinaceum*	–	–	–	–	–	–	x
P	*Sisyrinchium*	*albidum*	–	–	–	–	–	–	x
r	*Sisyrinchium*	*angustifolium*	–	–	–	–	–	–	x
	Sisyrinchium	***montanum***	x	x	x	x	x	x	–
r	*Sisyrinchium*	*mucronatum*	–	–	–	–	x	x	–
	Smilacina	***stellata***	x	x	x	x	x	x	x
	Solidago	*canadensis*	–	x	x	x	–	–	x
	Solidago	*gigantea*	–	–	x	–	–	–	–
	Solidago	*graminifolia*	–	x	–	–	–	–	x
	Solidago	*hispida*	x	x	x	x	x	x	x
PE	*Solidago*	*houghtonii*	–	–	–	–	x	x	–
	Solidago	***juncea***	x	x	x	x	x	x	x
	Solidago	***nemoralis***	x	x	x	x	x	x	x
E	*Solidago*	*ohioensis*	–	–	–	–	x	x	–
r	***Solidago***	***ptarmicoides***	x	x	x	x	x	x	–

APPENDIX 2. *Continued.*

STATUS	GENUS	SPECIES	WNY	SMI	NAP	CAR	BRU	MAN	WLE
P	*Solidago*	*rigida*	–	–	–	–	–	–	x
P	*Solidago*	*spath. rand. rac.*[1]	–	–	–	–	x	x	–
	Sorghastrum	*nutans*	–	–	–	–	–	–	x
	Spiraea	*alba*	x	x	–	x	x	x	–
	Spiranthes	*lacera*	x	–	–	x	x	x	–
P	*Spiranthes*	*magnicamporum*	–	–	–	–	–	–	x
	Spiranthes	*romanzoffiana*	–	–	–	–	x	x	–
P	*Sporobolus*	*asper*	–	–	–	–	–	–	x
P	***Sporobolus***	***heterolepis***	x	x	x	x	x	x	–
	Sporobolus	***vaginiflorus***	x	x	x	x	x	x	x
	Stellaria	*longipes*	x	–	x	–	–	–	–
P	*Stipa*	*spartea*	–	–	–	–	–	x	–
	Symphoricarpos	***albus***	x	x	x	x	x	x	x
	Symphoricarpos	*occidentalis*	–	–	x	–	–	–	–
	Taenidia	*integerrima*	–	–	x	–	–	–	–
r	*Thalictrum*	*confine*	–	–	–	–	–	x	–
	Thalictrum	*revolutum*	–	–	–	–	–	–	x
P	*Thaspium*	*barbinode*	–	–	–	–	–	–	x
P	*Thaspium*	*trifoliatum*	–	–	–	–	–	–	x
	Thuja	***occidentalis***	x	x	x	x	x	x	–
r	*Tofieldia*	*glutinosa*	–	–	–	–	x	x	–
X	*Tomanthera*	*auriculata*	–	–	–	–	–	–	x
	Toxicodendron	***radicans radicans***	x	x	x	x	x	x	x
r	***Trichostema***	***brachiatum***	x	x	x	x	x	x	x
r	*Triodanius*	*perfoliata*	x	–	x	–	–	–	–
	Triosteum	*perfoliatum*	–	–	x	–	–	–	–
r	*Trisetum*	*spicatum*	–	–	–	–	x	x	–
	Ulmus	*americana*	–	x	x	–	–	–	–
	Vaccinium	*angustifolium*	x	–	–	x	–	x	–
P	*Valerianella*	*umbilicata*	–	–	–	–	–	–	x
r	*Verbena*	*simplex*	–	–	x	–	–	x	x
P	*Vernonia*	*altissima*	–	–	–	–	–	–	x
	Veronica	***peregrina var.***[3]	x	x	x	x	x	x	x
	Viburnum	***rafinesquianum***	x	x	x	x	x	x	x
	Vicia	*americana*	–	x	x	–	–	–	–
	Viola	*affinis*	–	–	x	–	–	–	–
	Viola	*adunca*	–	–	–	x	–	–	–
	Viola	*conspersa*	–	–	x	–	–	–	–
	Viola	***nephrophylla***	–	x	x	x	x	x	–
	Virgulus	***ericoides***	–	–	x	–	–	–	x
	Virgulus	*novae–angliae*	x	–	–	–	–	–	x
	Vitis	*riparia*	x	–	x	–	–	–	x
	Zanthoxylum	*americanum*	x	x	x	–	–	–	x
r	*Zigadenus*	*glaucus*	x	–	x	x	x	x	x
r	*Zizia*	*aurea*	x	–	–	–	–	–	–
Number of sites			3	7	22	8	10	11	3
Total species			138	120	171	153	157	171	161
Total rare species (Ontario)			2	1	6	2	9	8	28
Total endemic species			0	0	0	0	7	5	1

[1] *Solidago spathulata* ssp. *randii* var. *racemosa.*
[2] subspecies and varieties were not determined.
[3] variety not determined.
[4] dismissed as ssp. *philadelphicus* by Sabourin and Paquette (1992*).
[5] identification of this and other *Epilobium* spp. requires more study.
[6] presumably native on northern Lake Huron alvars, but introduced elsewhere in southern Ontario. The varieties require more study (*see* Tardif and Morriset 1990).

The Extent of Confinement of Vascular Plants to Alvars in Southern Ontario

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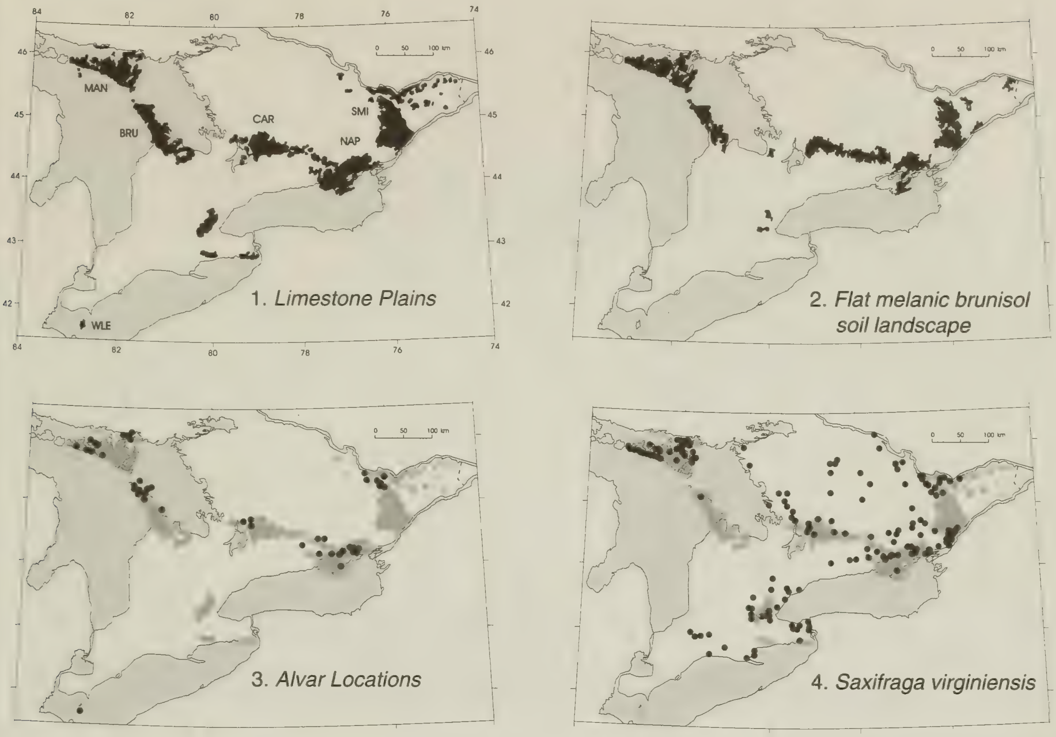
Fifty-four species of native vascular plants are shown to have the majority of their occurrences in Ontario on alvars. Of these, 32 have more than 70% of their Ontario occurrences on alvars, and 19 have more than 86% of their occurrences on alvars. Seventeen of the 54 species are considered provincially rare. Confined species include some that dominate alvar vegetation as well as some that are characteristically sparse. Alternate habitats for species largely confined to alvars include prairies (16 species), dune systems (15 species) and shores (11 species). Only the imperiled *Hymenoxys herbacea* is without an alternative habitat. The alvar-confined species are useful as indicators for the identification and evaluation of sites for protection and the geographic pattern they reveal as well as the variations within this pattern provide a basis for a system of protected representative sites. The alvar pattern primarily involves limestone plains and melanic brunisol soils along the edges of the Canadian Shield extending from Manitoulin Island and the Bruce Peninsula east to the Bay of Quinte and a more isolated region in the middle Ottawa valley as well as a few smaller areas such as the Niagara River and Pelee Island in southwestern Ontario. Confinement is probably largely a consequence of periodic drought and edaphic characteristics, but climate also appears to play a role in the restriction of confined species within the alvar landscapes. This may be especially true with respect to the southern elements in the mild western Lake Erie region. Boreal and endemic species of alvars in the northern Lake Huron region are believed to be periglacial relicts that have persisted in a cool environment.

Key Words: Alvar, limestone, phytogeography, rare species, endemic species, Ontario.

Alvars are natural openings where essentially flat limestone rock is at or near the surface (Catling et al. 1975). The sometimes sparse vegetation cover is comprised of herbs and shrubs, with trees scattered or absent. Several major plant associations occur on alvars, the most prevalent being grasslands, pavement edges, pavement ridges and savannas (Belcher et al. 1992; Catling and Catling 1993). Being seasonally moist, but subject to severe periodic drought (Stephenson 1983; Stephenson and Herendeen, 1986), alvars represent a special habitat and, not surprisingly, have a distinct native flora. Alvars occur primarily in southern Ontario and to a much lesser extent in southwestern Québec, New York, Vermont, Ohio, and Michigan (Catling and Catling 1995). Alvars are similar to limestone barrens to the north and east, to dry limestone prairies to the west, and to cedar glades to the south. The differences between alvars and these related communities are discussed by Catling and Catling (1995).

Within Ontario, their main area of occurrence in the Great Lakes region, alvars are restricted to a relatively small portion of the southern part of the province including the regions of limestone plains and more or less flat melanic brunisol soil landscapes (Figures 1 and 2). To some extent these features occur in the most densely populated and heavily impacted parts of Canada and consequently some of the botanically richest sites have been partially or totally destroyed over the past several years. The need to protect these sites has recently been publicized (e.g., Belcher and Keddy 1992; Catling and Catling 1995) and the Nature Conservancy has established several characteristic alvar plant communities as "globally imperiled" (Catling and Catling 1995). Alvars are important as (1) habitats for numerous rare plants and animals, (2) distinctive environments affording special opportunities for certain kinds of scientific research, (3) as sources of native germplasm of drought-tolerant races of certain crops and crop relatives such as strawberries, saskatoons and currants, (4) areas of exceptional natural beauty in terms of wildflower displays, and (5) sensitive benchmarks for documentation of effects of environmental change.

Initially, it was the disturbance and nutrient inputs of grazing livestock that resulted in the replacement of native alvar species with an aggressive alien (Eurasian) flora (Catling and Catling 1995). On the other hand, grazing by livestock may prevent marginal alvar sites from becoming overgrown, thus maintaining habitat for Loggerhead Shrikes, *Lanius ludovicianus*. While grazing continues to be a major threat to alvar flora, quarrying and residential development are rapidly increasing in their impact. A sustainable agricultural landscape and effective landuse planning in general require that an adequate system of representative sites be established and protected, but this in turn requires a better understanding of the characteristics and geographic distribution of alvar



FIGURES 1–4. Southern Ontario showing limestone plains, melanic brunisol soil landscapes and alvar locations and plant distributions (based on herbarium specimens) in relation to these physiographic features. 1. Limestone plains (shaded) after Chapman and Putnam (1984) with 5 major regions indicated, BRU = Bruce Peninsula, CAR = Carden Plain, MAN = Manitoulin Island, NAP = Napanee Plain, SMI = Smiths Falls Plain, and WLE = Western Lake Erie. 2. Melanic brunisol soil landscapes (shaded) provided by B. Edwards and after Edwards (1988). 3. Locations of 45 undisturbed alvars studied. 4. *Saxifraga virginiensis*.

vegetation. The specific objectives of this work were (1) to elucidate indicator species and predictable patterns of occurrence that could be used in the identification and evaluation of sites for protection and research, and (2) to contribute to an understanding of the geography and origin of alvar vegetation.

Methods

Based on (1) notes and collections from a field survey of alvars in Ontario, conducted from 1987 to 1993, which included 45 undisturbed and over 100 disturbed sites, as well as (2) habitat data on labels of herbarium specimens from the herbaria of the Canadian Museum of Nature (CAN), Agriculture Canada (DAO) and the Royal Ontario Museum (TRT), the extent to which various native species are confined in Ontario to alvar habitats was assessed. The field survey involved one week on Manitoulin Island, one week on the Bruce Peninsula, and approximately 30 days allocated to limestone plains elsewhere in southern Ontario (Chapman and Putnam 1984). Equal or far greater amounts of time were allocated to field reconnaisance of areas near to the various limestone plains. This, and the use of herbarium data, served to ensure that confinement was not an artifact of preoccupation with the significant alvar habitats. Since overall field experience in southern Ontario was also applied to an evaluation of the level of confinement, it was appropriate to establish three levels of confinement rather than dealing with absolute figures which were subjective to start with. The three levels established were: moderate = 50-70%, high = 71-85%, very high = 86-100%. Confinement is based on approximate proportion of occurrences on alvars *versus* total occurrences, where an occurrence is defined as a collection at least one km away from any other collection.

Some species are confined to alvar habitat in Ontario, but are known from only one site in the province. Such species, although of great interest, are of less value in characterizing alvar vegetation than species that occur in most regions where alvars occur. To enable comparisons between species with respect to significance of confinement, the number of alvar regions (Figure 1) within which various species occurred was recorded (Table 1).

TABLE 1. Vascular plant species which have approximately 50% or more of their stations in southern Ontario on alvars. BRU = Bruce Peninsula; CAR = Carden Plain; MAN = Manitoulin Island; NAP = Napanee Plain; SMI = Smiths Falls Plain; WLE = Pelee Island. For levels of confinement moderate (*) = 50-70%, high (**) = 71-85%; very high (***) = 86-100%. **Species considered to be rare in Ontario are indicated by bold face type.**

Species	Level of confinement	Alvar region	Other habitats in southern Ontario[1]
Allium cernuum, Nodding Wild Onion	**	WLE	cliff, sand
Allium schoenoprasum[2], Wild Chives	***	MAN	shore (footnote)
Amelanchier alnifolia[3], Saskatoon	*	all	prairie, field, sand
Anemone multifida, Anemone	*	BRU, MAN	dune
Arabis hirsuta, Rock-cress	*	all	cliff
Aster pilosus[4], Pringle's Aster	*	all but WLE	dune
Astragalus neglectus, Cooper's Milk-vetch	**	CAR, NAP, SMI	sand
Blephilia ciliata, Downy Wood Mint	***	WLE	none
Bouteloua curtipendula, Side Oats Grama	**	NAP	prairie, savanna
Bromus kalmii, Kalm's Brome	*	all but WLE	prairie, rock barren
Calamintha arkansana, Calamint	*	BRU, MAN, WLE	shore, dune slack
Cardamine parviflora, Bitter Cress	*	all	barren
Carex crawei, Crawe's sedge	***	all	dune slack, shore
Carex juniperorum, Juniper Sedge	***	NAP	woodland
Carex richardsonii, Richardson,s Sedge	***	all but WLE	prairie, savanna, barren
Carex scirpoidea, Bulrush Sedge	**	BRU, MAN	shore
Castilleja coccinea, Scarlet Painted-cup	*	BRU, CAR, MAN, NAP	bluff, prairie, dune
Ceanothus herbaceus, New Jersey Tea	*	all	prairie, dune, barren
Cirsium hillii, Hill's Thistle	**	BRU, MAN	dune
Coreopsis lanceolata, Coreopsis	***	BRU, MAN	roadside
Deschampsia caespitosa, Tufted Hair Grass	**	BRU, CAR, MAN, NAP	shore, mine waste
Draba reptans, Carolina Whitlow-grass	*	NAP	sandy shore
Eleocharis compressa, Flattened Spike-rush	***	all but SMI	dune hollow (rarely)
Euphorbia commutata, Tinted Spurge	***	NAP	barren (marble), cliff
Geranium carolinianum, Carolina Cranesbill	***	all but SMI	sandy shore, barren
Geum triflorum, Prairie Smoke	***	CAR, MAN, NAP	prairie
Hymenoxys herbacea, Lakeside Daisy	***	BRU, NAN, WLE	none
Hypericum kalmianum, Kalm's St. John'-wort	*	BRU, MAN	dune, shore, fen
Iris lacustris, Dwarf Lake Iris	*	BRU, MAN	woodland, dune
Juniperus horizontalis, Creeping Juniper	*	BRU, MAN	shore, dune, sand
Liatris cylindracea, Cylindric Blazing-star	*	MAN	prairie, dune
Muhlenbergia glomerata, Muhly	*	all but WLE	prairie, fen, dune
Myosurus minimus[5], Mousetail	***	NAP	none (footnote)
Myosotis verna, Vernal Forget-me-not	***	NAP, MAN, WLE	roadside, barren
Panicum flexile, Panic-grass	**	CAR, NAP, SMI, WLE	dune slack, shore
Panicum philadelphicum, Panic-grass	**	CAR, NAP, SMI, WLE	roadside, shore
Pellaea atropurpurea, Purple Cliff-brake	*	BRU, MAN	cliff, marble barren
Phacelia purshii, Miami Mist	*	WLE	woodland

TABLE 1. Concluded

Species	Level of confinement	Alvar region	Other habitats in southern Ontario[1]
Piperia unalascensis, Alaskan Orchid	***	BRU, MAN	open conifer wood
Poa alpina, Alpine Bluegrass	**	BRU, MAN	cliff, shore
Polygala senega, Seneca-snakeroot	**	all	woodland, prairie, dune
Potentilla fruticosa, Shrubby Cinquefoil	*	BRU, CAR, MAN, WLE	shore, fen, dune
Ranunculus fascicularis, Early Buttercup	**	all but BRU	prairie
Rhus aromatica, Fragrant Sumac	*	all but SMI	barren, prairie, dune
Saxifraga virginiensis, Early Saxifrage	*	all but WLE	prairie, barren
Scutellaria parvula, Small Skullcap	**	all	shore, dune slack
Senecio pauperculus, Ragwort	*	all	marble barren, meadow
Solidago houghtonii, Houghton's Goldenrod	***	BRU, MAN	none
Solidago ptarmicoides, Upland Goldenrod	***	all but WLE	dune, prairie, barren
Solidago spathulata[6], Rand's Goldenrod	*	BRU, MAN	shore, dune, cliff
Sporobolus heterolepis, Northern Dropseed	***	all but WLE	prairie
Trichostema brachiatum, False Pennyroyal	***	all	prairie, roadside
Valerianella umbilicata, Corn-salad	***	WLE	none
Verbena simplex, Simple Vervain	**	all but BRU	quarries, disturbed sites

[1]"dune" may include either dune crests or slopes or periodically moist dune slacks; "barren" refers to granite, amphibolite or marble barrens which may or may not have a light calcareous overburden.

[2]The plant that occurs rarely throughout southern Ontario is presumably of Eurasian origin (var. *schoenoprasum*), while the alvar plants are presumably referrable to either of the native varieties (var. *laurentianum* or var. *sibiricum*).

[3]var. *compacta*

[4]var. *pringlei*

[5]Native race of uncertain rank probably confined to alvars

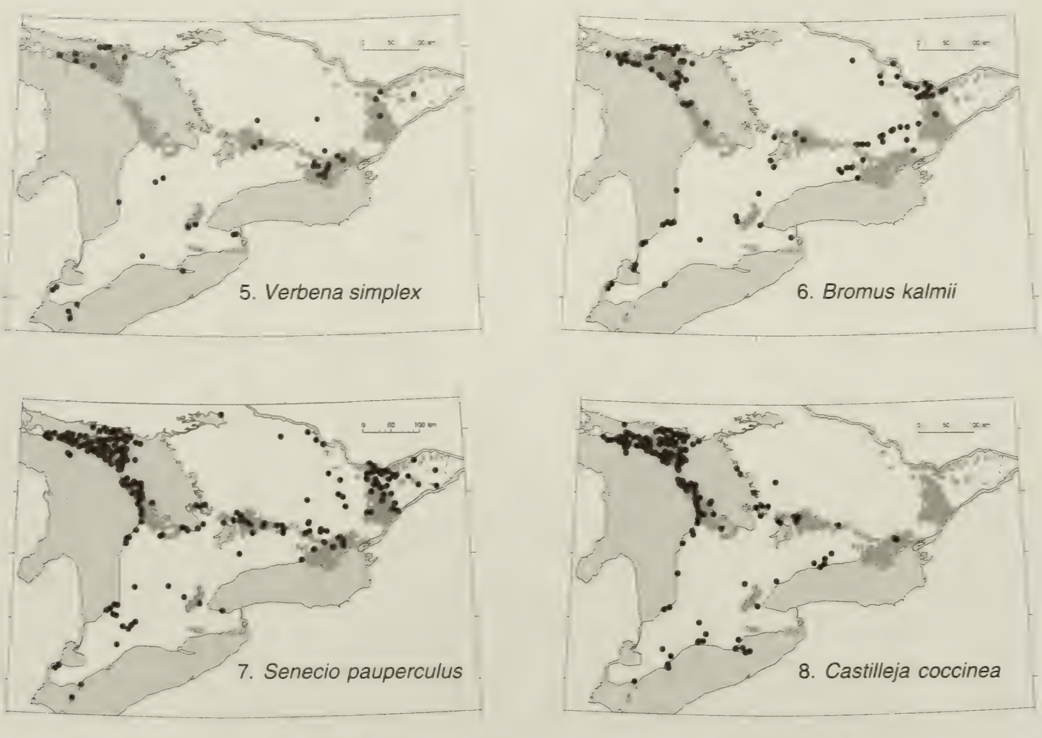
[6]ssp. ***randii*** var. ***racemosa***

To explore the phytogeographic pattern of alvar vegetation in Ontario and further evaluate confinement, the geographical distribution of potential alvar landscapes was compared with plant distribution patterns. The limestone plains map was redrawn from Chapman and Putnam (1984). Since most Ontario alvars occur within the combined area of limestone plains and more or less flat melanic brunisol soil landscape (melanic brunisol of loamy texture with morainal parent material, either undulating or hummocky with slopes of 0 to 9%; i.e., Llm Mu1 Ml4, see Edwards, 1988; Shields et al. 1991), these two largely but not completely overlapping features represent potential alvar landscape for correlation with plant distributions. Base maps were produced using the Canada Soil Information System in the cartography unit of the Land Resource Division of the Centre for Land and Biological Resources Research of Agriculture Canada. The soil landscape associated with alvar sites and the plant distributions were also plotted using this system. All dot distribution maps for plants are based on specimens at the herbaria listed above, with some additional records from the herbaria at the University of Michigan (MICH), and the University of Waterloo (WAT), and also from the Canadian Museum of Nature's rare Ontario plant database. Authorities for scientific names may be found in Morton and Venn (1990).

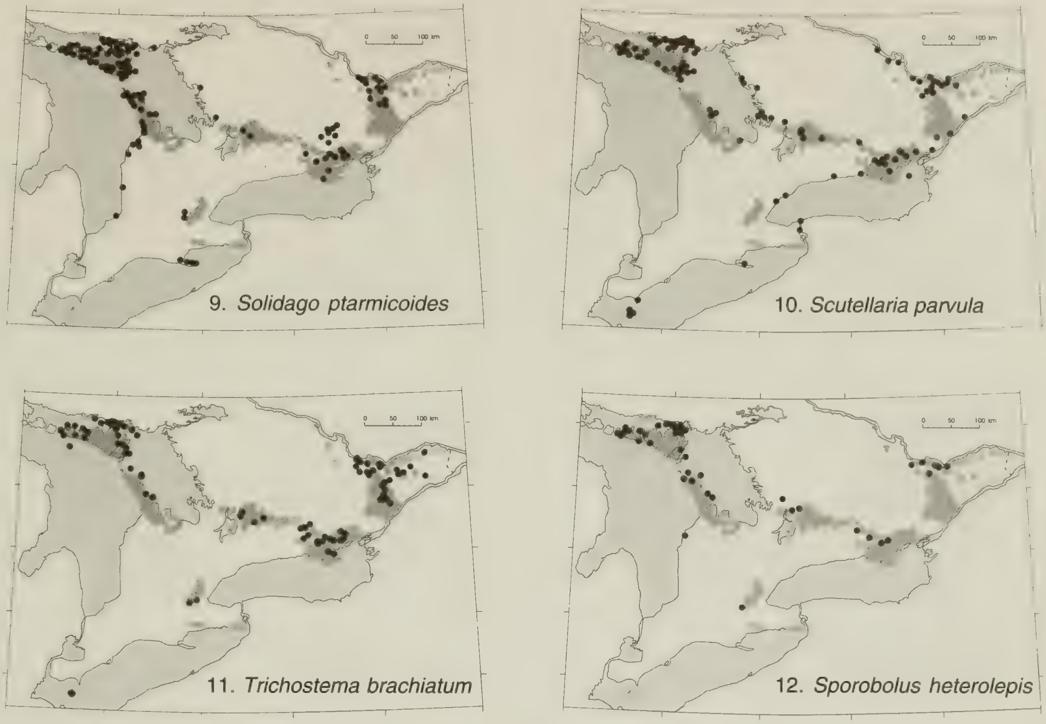
Results and Discussion

Limestone plains and the flat melanic brunisol soil landscape are largely, but not entirely overlapping (cf. Figures 1 and 2). Forty-five of the best (in terms of native species diversity, rare species presence, and lack of disturbance) alvar sites in Ontario occur within the region of limestone plains physiography (Figure 3), which thus appears to be a fairly reliable "alvar landscape". This landscape corresponds approximately to the edges of the Canadian Shield extending from Manitoulin Island east to the Napanee plain with a break where the Frontenac axis crosses the St. Lawrence River, but with the landscape resuming again on the east and north side of the Frontenac axis on the Smiths Falls limestone plain. The relevant exceptions to this general pattern are the Flamborough plain north of the western end of Lake Ontario, a few alvars along the Niagara River in the eastern Lake Erie region, and those in the western Lake Erie region, which in Ontario are confined to Pelee Island.

Fifty-four species are shown in Table 1 that have the majority of their occurrences in southern Ontario



FIGURES 5–8. Distributions of vascular plants in southern Ontario (based on herbarium specimens) in relation to limestone plains (shaded). 5. *Verbena simplex*. 6. *Bromus kalmii*. 7. *Senecio pauperculus*. 8. *Castilleja coccinea*.

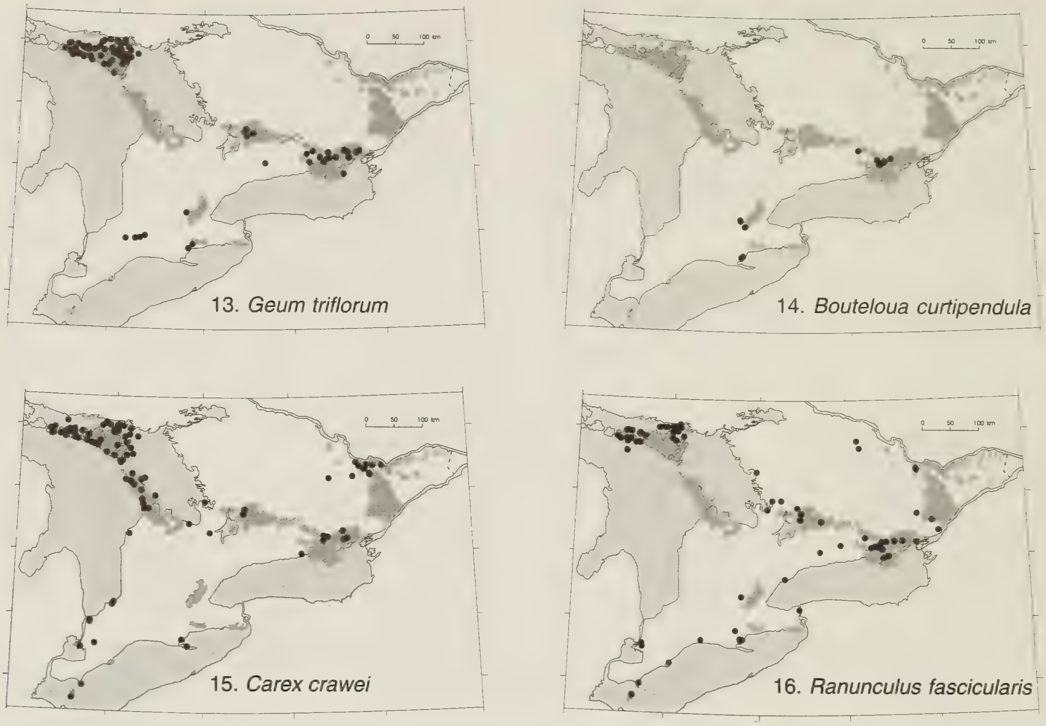


FIGURES 9–12. Distributions of vascular plants in southern Ontario (based on herbarium specimens) in relation to limestone plains (shaded). 9. *Solidago ptarmicoides*. 10. *Scutellaria parvula*. 11. *Trichostema brachiatum*. 12. *Sporobolus heterolepis*.

on alvars. Of these, 32 have more than 70% of their Ontario occurrences on alvars, and 19 have more than 86%. Many of these species, including species with a very high level of confinement, occur in three or more of the major alvar regions. The very close correspondance of the distribution of many of these species to the alvar landscape is shown in Figures 3-24.

As the extent of confinement (Table 1) increases, the extent of association with the alvar landscape on distribution maps also increases. *Trichostema brachiatum* (Figure 11), with over 95% of its Ontario locations on alvars, is entirely confined to the alvar landscape on the basis of the specimens examined. Although this species sometimes occurs in roadside ditches, it is usually close to natural occurrences in periodically moist depressions in very shallow soil of natural alvar openings. Among the other species with a very high level of confinement (Table 1) within southern Ontario to alvars, and a correspondingly high correlation with the alvar landscape, are *Carex crawei* (Figure 15), *Geum triflorum* (Figure 13), *Ranunculus fascicularis* (Figure 16), *Scutellaria parvula* (Figure 10), *Solidago ptarmicoides* (Figure 9), and *Sporobolus heterolepis* (Figure 12).

Few species largely confined to alvars in Ontario are without alternative habitats in the province (Table 1), and most of those have other habitats elsewhere. The only species that is confined globally to alvars, and has most of its populations in Ontario, is *Hymenoxys herbacea*, considered imperiled in Canada and critically imperiled in the United States (Argus and Pryer 1990). The extent of restriction to alvars is generally not a consequence of the scarcity of alternative habitats in Ontario, since most of the species do not exploit these aternative habitats, such as fens, prairies, or even dune complexes, to the extent possible based on the occurrence of these habitats. The most frequent alternative habitats for species largely confined to alvars in Ontario are prairies (16 species), dune systems (15 species) and shores (11 species). *Bouteloua curtipendula* (Figure 14), *Carex richardsonii* (Figure 20), *Geum triflorum* (Figure 13), *Ranunculus fascicularis* (Figure 16) and *Sporobolus heterolepis* (Figure 12) also occur on calcareous sandy prairies and savannas (e.g. Catling and Catling 1993). Interestingly, *Sporobolus heterolepis* is primarily a plant of fens in southern Michigan. *Carex crawei* (Figure 15), *Scutellaria parvula* (Figure 10), and *Solidago ptarmicoides* (Figure 9) also occur in dune



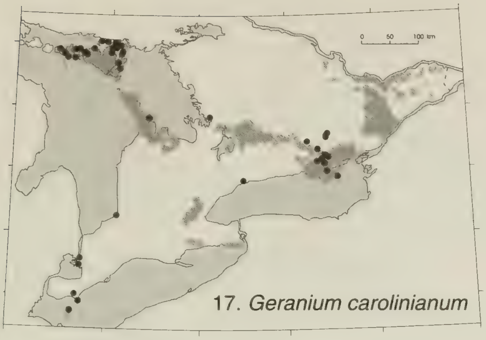
FIGURES 13–16. Distributions of vascular plants in southern Ontario (based on herbarium specimens) in relation to limestone plains (shaded). 13. *Geum triflorum*. 14. *Bouteloua curtipendula*. 15. *Carex crawei*. 16. *Ranunculus fascicularis*.

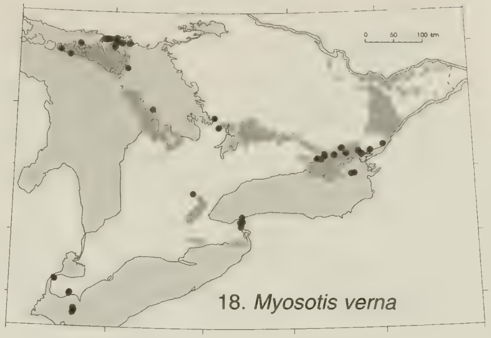
slacks as suggested by their southern Ontario distributions. *Geranium carolinianum* (Figure 17), *Draba reptans* (Figure 22), and *Myosotis verna* (Figure 18) grow on sandy flats and strands as well as on alvars. A less frequent alternative habitat is cliffs, particularly of dolomite and marble, which are the alternative habitats of species such as *Euphorbia commutata* (Figure 21) and *Pellaea atropurpurea* (Figure 19). Since more or less flat limestone shorelines exceeding 50 m in width and above the high water level are accepted as alvars here, a few species such as *Hypericum kalmianum* and *Solidago spathulata* are included within the group of confined species, but would be excluded if the definition was limited to only inland sites or more extensive shoreline exposures.

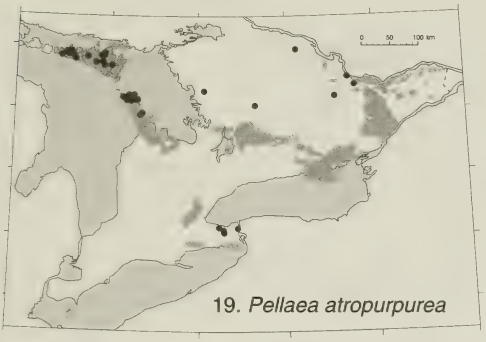
Species with approximately 50% of their occurrences on alvars, such as *Bromus kalmii* (Figure 6), *Castilleja coccinea* (Figure 8), , *Rhus aromatica*, *Saxifraga virginiensis* (Figure 4), and some species with less than 50% of occurrences on alvars such as *Juniperus communis* var. *depressa*, *Shepherdia canadensis* and *Viburnum rafinesquianum*, are nevertheless closely associated with the alvar landscape. In general, these species are frequent on alvars but also occur in other habitats that are common within or near to some of the alvar landscapes, such as fens, limestone rock exposures, granite balds with calcareous overburden, open calcareous sands, and open calcareous seepage slopes.

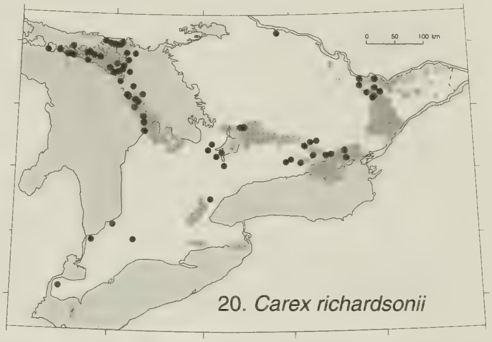
Widespread species associated with the alvar landscape range from those that are locally abundant or even dominant on alvars such as *Senecio pauperculus* (Figure 7) and *Sporobolus heterolepis* (Figure 12) to some that are uncommon and generally sparse such as *Verbena simplex* (Figure 5). Some species largely confined to alvars and to the alvar landscape region are found in only a restricted portion of it. Within the alvar landscape of southern Ontario, *Bouteloua curtipendula* (Figure 14) is confined to the Napanee Plain. *Geum triflorum* (Figure 13), *Geranium carolinianum* (Figure17) and *Myosotis verna* (Figure 18) are absent from the Smiths Falls Plain and the Bruce Peninsula. Boreal species such as *Carex scirpoidea* (Figure 24), the cordilleran *Piperia unalascensis*, and endemics such as *Hymenoxys herbacea* (Figure 23) are confined to the alvars of the Bruce Peninsula and Manitoulin Island.

The western Lake Erie alvars and those of the Bruce Peninsula, Manitoulin Island, and the Napanee Plain are the richest alvar regions and each of them has some unique elements. Since the sites









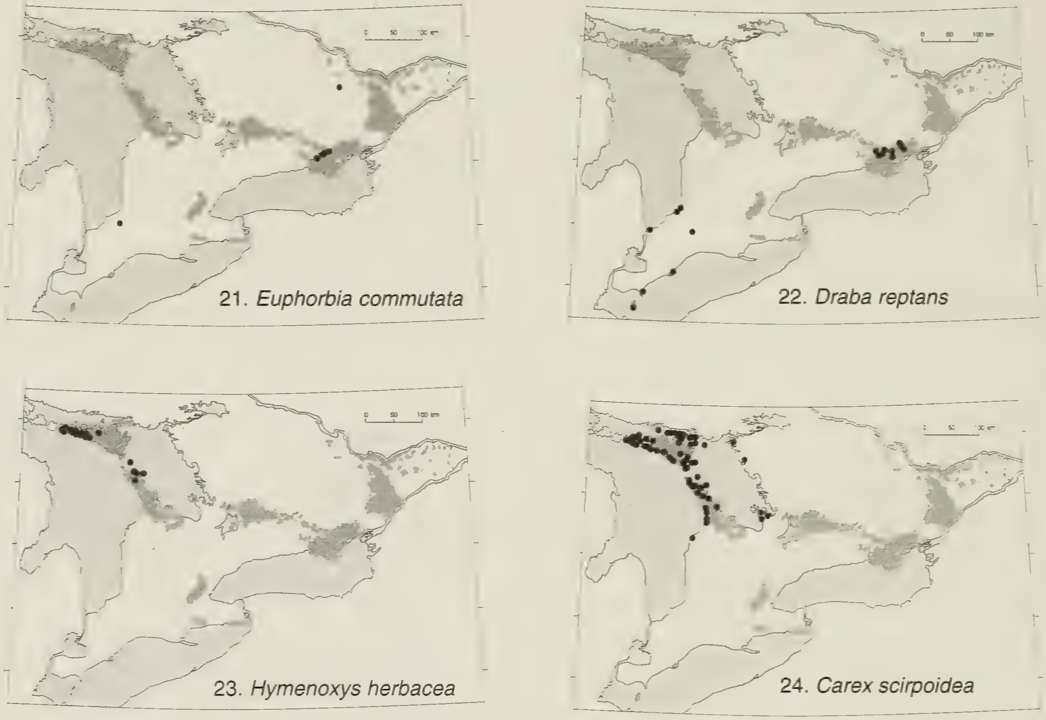
FIGURES 17–20. Distributions of vascular plants in southern Ontario (based on herbarium specimens) in relation to limestone plains landscapes (shaded). 17. *Geranium carolinianum*. 18. *Myosotis verna*. 19. *Pellaea atropurpurea*. 20. *Carex richardsonii*.

are in different climatic regions of southern Ontario, climate alone could account for some of this variation (Brown et al. 1980). Numerous species are found in Ontario only on the Stone Road alvar on Pelee Island, or on other alvars of the western Lake Erie region, but these are too restricted to be of much use in defining alvar vegetation at the provincial level. Species restricted to this part of the pattern are largely southern and midwestern elements at their northern limits existing in a part of southern Ontario that has an exceptionally mild climate.

The presence of the boreal and cordilleran species such as *Carex scirpoidea*, *Piperia unalascensis* and *Poa alpina*, as well as endemics including *Cirsium hillii*, *Hymenoxys herbacea*, *Iris lacustris* and *Solidago houghtonii*, on the alvars in Bruce Peninsula and Manitoulin sites may be explained with respect to the cool, dry environment and continuous availability of disturbed habitats. This situation probably approximates that which existed more than 10 000 years ago along the Wisconsin ice front and in the *Picea* parkland near to it (Webb 1987). Although some upper Great Lakes sites may have been under water in very early postglacial times, they were probably connected and more extensive by 9500 years ago (Lewis and Anderson 1989), at a time before climatic and vegetation zones had moved substantially northward. Furthermore, they may have been above water to the present since the precursor of Lake Huron was smaller than the present lake.

In addition to vascular plants, there are some bryophytes that are more or less restricted to alvars. Examples include *Scorpidium turgescens* and *Riccia sorocarpa*.

With a high level of species confinement and phytogeographic pattern, alvars are a distinctive feature of the natural landscape of southern Ontario. The species well represented throughout the alvar landscape and largely confined in Ontario to alvars are presumably a group narrowly adapted to the combined characters of periodic drought (Stephenson and Herendeen 1986) and calcareous soil. These indicator species largely confined to alvars, including 17 that are considered provincially rare (Table 1), may be used to assist in the selection and evaluation of optimal sites for protection. The alvar geographic pattern, based on both species and sites, enables the occurrence of alvars to be predicted, and the regional variations within this pattern suggests that sites will have to be protected within the different regions if an adequate system of representative sites is to be established.



FIGURES 21–24. Distributions of vascular plants in southern Ontario (based on herbarium specimens) in relation to lime–stone plains (shaded). 21. *Euphorbia commutata*. 22. *Draba reptans*. 23. *Hymenoxys herbacea*. 24. *Carex scirpoidea*.

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Status of Blanding's Turtles, *Emydoidea blandingii*, in Nova Scotia, Canada*

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Blanding's Turtle, *Emydoidea blandingii*, is a northern freshwater species with a distribution centered in the Great Lakes region. Numerous isolated populations exist along the periphery of the range; of these, the Nova Scotia population is the most isolated. Most individuals in the Nova Scotia population occur within Kejimkujik National Park in southwest Nova Scotia, where they are confined primarily to three centres of activity, all associated with darkly coloured waters and peaty soils. Capture-mark-recapture and radiotracking data show long-distance nesting migrations by females and exceptionally long overland movements by some males. This vagility, in combination with observations of promiscuous mating, suggests the Nova Scotia population is panmictic. Historical and recent records show that scattered individuals occur in low numbers outside the Park. The adult population within the Park is estimated to be 132 (95% confidence intervals: 99-179). Densities are substantially lower than those reported for other populations. The age structure in this population appears top-heavy; of 48 individuals aged, 31 exceeded 30 years. This suggests that longevity and reproductive lifespan are extended, but that recruitment is low. Reproductive potential is apparently compromised by: (1) the limited availability of suitable nesting areas (substrate, exposure, susceptibility to flooding); and (2) low egg and hatchling survivorship (due to raccoon predation, flooding and a short growing season). These factors, in combination with late age at maturation, underline the importance of high survivorship of breeding adults to the continued existence of this population. The recommended status of the Nova Scotia Blanding's Turtle population is threatened.

Key Words: Blanding's Turtle, *Emydoidea blandingii*, Nova Scotia, Kejimkujik National Park, disjunct population, status, threatened.

Blanding's Turtle, *Emydoidea blandingii*, is a relatively large North American freshwater turtle (subfamily: Emydinae). Its patchy distribution is centered in the Great Lakes region of Canada and the United States (Iverson 1992). The high-domed, slaty-coloured carapace with variable yellow flecking, long neck, and yellow throat are characteristic (Figure 1) of adults.

Distribution

Blanding's Turtle is a northern freshwater species with a distribution centered in the Great Lakes region (Cahn 1937; Conant 1938; Lagler 1943; Breckenridge 1944; Pope 1949; Carr 1952; Bleakney 1958a, 1963; Anderson 1965; Preston and McCoy 1971; Ernst and Barbour 1972; Pritchard 1979; Gilhen 1984; (for review see McCoy 1973)). The species' main range (Figure 2) extends from extreme southwestern Quebec and southern Ontario south and west to central Nebraska including parts of Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, Iowa, Missouri, and South Dakota. Isolated populations occur farther east in New York, Massachussetts, New Hampshire, Maine and Nova Scotia.

Throughout its range, Blanding's Turtle is patchily distributed, especially in peripheral regions (McCoy 1973). In Ontario, recent efforts by the Ontario Herpetofaunal Summary and others yielded additional records but did not extend appreciably the known range of the species northward (Petokas and Alexander 1980; Weller and Oldham 1988). Small peripheral populations have been identified or substantiated in Maine (Graham and Doyle 1973; Graham et al. 1987), Massachussetts (Graham 1986), New York (Petokas and Alexander 1981), Minnesota (Ernst 1973; Olson 1987) and Wisconsin (Cochran and Lyons 1986). The range of Blanding's Turtle may have decreased in recent times due to loss of habitat (Cahn 1937; Jackson and Kaye 1974). In Missouri for example, it has been extirpated from several pockets in the northeast (Kofron and Schreiber 1985).

Blanding's Turtle was first described from Nova Scotia in 1953, on the basis of a large female discovered near Kejimkujik Lake (Bleakney 1958a). Despite recent searches in peripheral areas the

*Status report accepted by The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) April 1993. Designation: Threatened (Nova Scotia population).

FIGURE 1. Blanding's Turtle, *Emydoidea blandingii,* below Grafon Lake, Kejimkujik National Park, July 1981. Photograph by Jamie Steeves, courtesy Parks Canada.

species' known range remains restricted to parts of the Mersey and Medway River watersheds (Powell 1965; Dobson 1971; Weller 1973*[1]; Bleakney 1976*; Drysdale 1983*; Herman et al. 1989*) (Figures 3, 4). The Nova Scotia population is the most isolated single disjunct in the entire range of

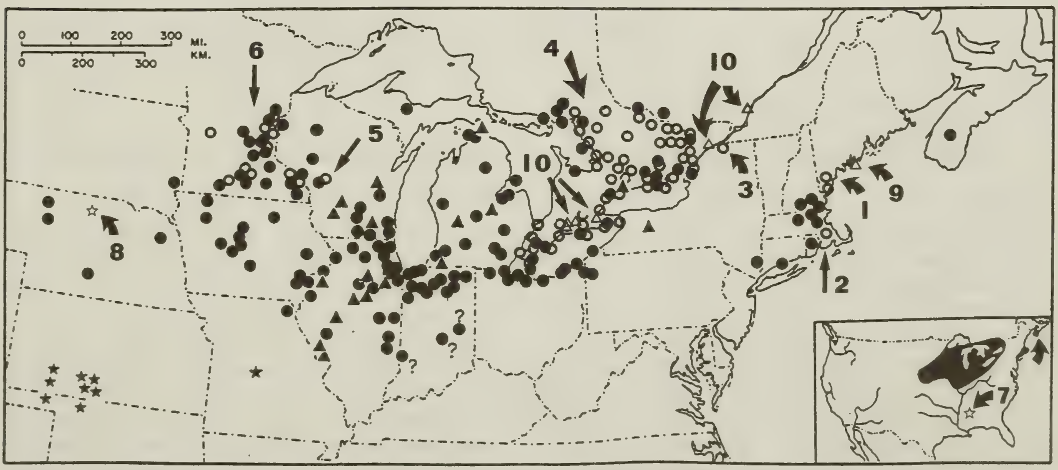

FIGURE 2. Past and present distribution of *Emydoidea blandingii* after McCoy (1973) (closed symbols), with updated information (open symbols). Circles represent extant populations, stars represent fossil finds, triangles represent archeological finds. Numbers refer to references for updated information as follows: extant populations: 1-Maine (Graham and Doyle 1973; Graham et al. 1987), 2 - Massachussets (Graham 1986), 3 - New York (Petokas and Alexander 1978, 1981), 4 - Ontario (Petokas and Alexander 1980; Weller and Oldham 1988), 5 - Wisconsin (Cochran and Lyons 1986), and 6 - Minnesota (Ernst 1973; Olson 1987); fossil records: 7 - Mississippi (Jackson and Kaye 1974), and 8 - Nebraska (Hutchison 1981); archeological finds: 9 - Maine (French 1986), 10 - Quebec and Ontario (Bleakney 1958b; Bider et Matte 1991).

*Citations marked with an asterisk are unpublished documents and are listed separately following the A186cknowledgments and before the Literature Cited section.

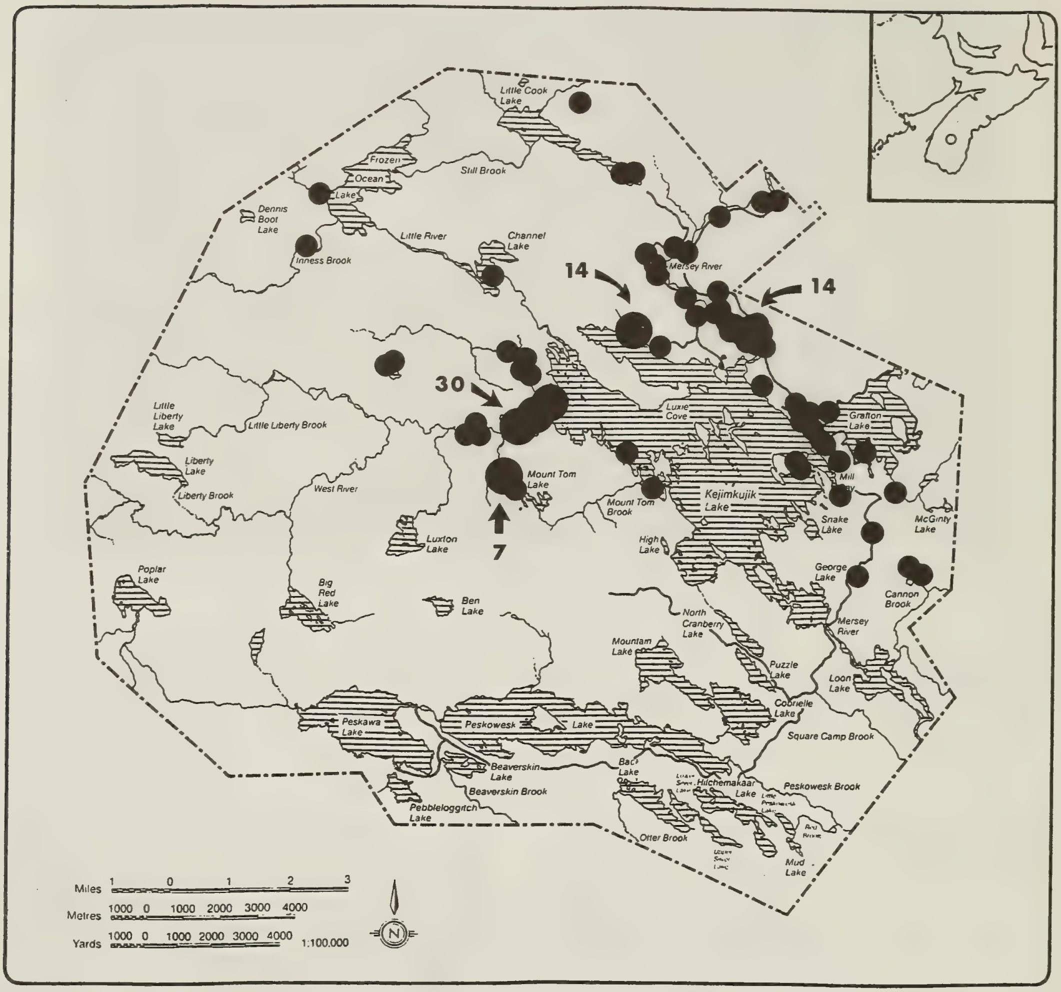

FIGURE 3. Distribution of *Emydoidea blandingii* in Kejimkujik National Park, Nova Scotia. Solid circles indicate sitings of different individual turtles (n=119) between 1952-1991; numbers indicate the numbers of turtles observed in three areas of concentration.

the species and is considered a relict from a warmer climatic period (Bleakney 1958a).

Although nothing is known of the history of the species in Nova Scotia, a comparison of past and present distributions of *Emydoidea blandingii* elsewhere shows a considerable change in the range of the turtle (Figure 2). Fossil specimens have been found in Kansas (Pleistocene) (Preston 1971), Nebraska (Miocene) (Hutchison 1981), Mississippi (Pleistocene) (Jackson and Kaye 1974), and Oklahoma and Missouri (late Pliocene to Pleistocene) (Preston and McCoy 1971). Archeological evidence of Blanding's exists from Ontario and Quebec (Bleakney 1958b), Maine (French 1986), Michigan (Adler 1968), Illinois, New York, Wisconsin, and Missouri (Preston and McCoy 1971). The fossil evidence, which occurs to the south and west of the present centre of distribution, suggests that the species moved from west to east in the geologic past. This movement may have resulted from habitat disappearance (Jackson and Kaye 1974), or changing climatic conditions (Preston 1971).

Archeological findings that suggest subsequent extinctions have occurred in some peripheral areas. This pattern may have resulted from the use of the Atlantic Coastal Plain as a glacial refuge, with post-glacial dispersal occurring north, east, and west from this area (Bleakney 1958a). Alternatively, the plains may have served as the glacial refuge, with post-glacial dispersal occurring along a "steppe corridor" (Schmidt 1938) to the east (Preston and McCoy 1971; Porter 1972). The

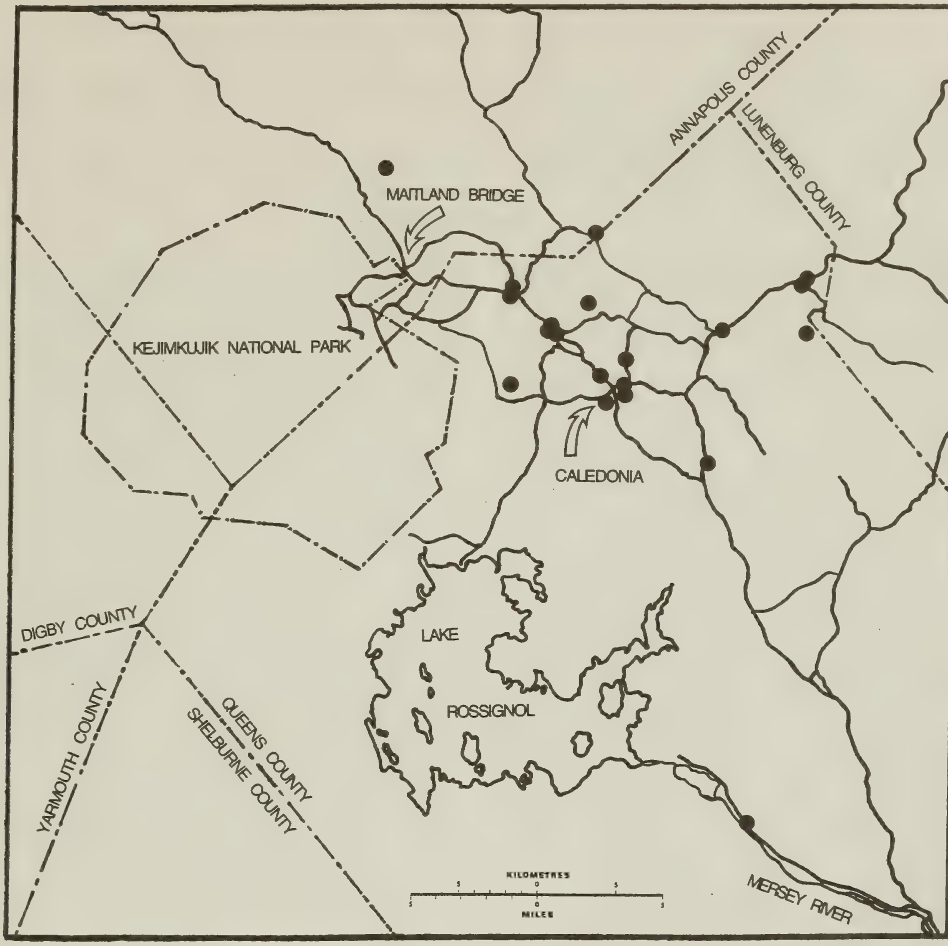

Figure 4. Recorded sightings of Blanding's Turtle in Nova Scotia outside Kejimkujik National Park.

present patchy distributional pattern in the east, combined with the southwestern fossil records and the more easterly archeological evidence seem to support this latter hypothesis.

Protection

Blanding's Turtle is protected in New York (status: threatened), Michigan, and Minnesota (threatened), is considered at risk in Missouri (endangered) (Kofron and Schreiber 1985), Wisconsin (threatened) (Ross 1989), Maine (threatened), New Hampshire, Massachusetts (threatened), Iowa, and South Dakota (threatened) has been recognized to be of special concern in Pennsylvania (Petokas 1986), Indiana, Ohio, Ontario, and Quebec, and is extirpated in Rhode Island and Connecticut (T. E. Graham, personal communication). In Canada, this species is protected (i.e. may not be collected or disturbed) in all National Parks where it occurs, including Kejimkujik National Park in Nova Scotia. At the provincial level the species has been protected since 1984 under the Game and Fish Act in Ontario, and since 1990 under the Nova Scotia Wildlife Act. Blanding's Turtle has no official status in Quebec.

Population Size

The Nova Scotia population of adult Blanding's Turtle within Kejimkujik National Park is estimated to be 132 (95% confidence intervals: 99.4 - 178.9) (Schnabel binomial estimate). This estimate was derived from a comparison of census data from three discrete marking intervals between 1969 and 1988 (1971-1972, 1977-1979, 1987-1988). A Petersen estimate of population size, based on mark and recapture work in 1987 and 1988, was similar (125.2; 95% confidence intervals: 108.8 - 154.9). These estimates assume the population is closed. The limited recruitment of young turtles into the

population and the restricted distribution of this population minimizes bias in the estimate.

Historical records indicate that scattered individuals are present outside the park, almost exclusively to the east, and are associated with peaty substrates on slate bedrock. Despite local interest in and public awareness of the species in this area, reported sightings are rare. It is unlikely that this population is large.

Habitat

Emydoidea blandingii is believed to have originally inhabited prairie marshes (Cahn 1937; Smith 1961, in Preston and McCoy 1971); present-day macro-habitats vary, and include lakes, ponds, marshes, low fields, ditches, creeks, river sloughs and bogs (Conant 1938; Lagler 1943; Breckenridge 1944; Pope 1949; Carr 1952; Adams and Clark 1958; Preston and McCoy 1971; Ernst and Barbour 1972; Ernst 1973; Graham and Doyle 1979; Gilhen 1984; Kofron and Schreiber 1985; Ross 1989; Ross and Anderson 1990). The increased variety of habitats presently used by the species may have resulted partly from habitat destruction in its original range (Cahn 1937; Jackson and Kaye 1974), as well as from changing climatic conditions (Preston 1971).

Within these macro-habitats, the species is associated with shallow water vegetated with submergent or emergent plants (Conant 1938; Pope 1949; Carr 1952; Adams and Clark 1958; Ernst and Barbour 1972; Gilhen 1984; Kofron and Schreiber 1985; Ernst and Barbour 1989), often with deep organic sediments (Ernst and Barbour 1972; Graham and Doyle 1979; Ross 1989; Ross and Anderson 1990).

In Nova Scotia, the distribution of Blanding's Turtle closely parallels that of highly coloured acid waters and peaty soils (Power et al., 1994). Mark-recapture and radio-tracking data as well as reproductive activity showed that turtles maintained three discrete centres of activity in Kejimkujik National Park (Figure 4), each associated with darkly coloured rivers and streams (Power et al. 1994).

General Biology

Age Structure

Age of Blanding's Turtles in Nova Scotia was estimated from impressions of growth annuli on the dorsal surface of femoral and anal scutes recorded in dental registration paste (Herman et al. 1989*). Relatively clear impressions were obtained from 49 individuals (19 males, 24 females, 5 juveniles). Of these, 31 exceeded 30 years of age; one female was estimated to be 73. There were only three adults (15 years or older) under 26 years of age. The preliminary analysis of age structure in the Nova Scotia population suggests that longevity of adults is extended but that recruitment to the breeding population is low.

Aging of turtles under 30 was usually straightforward; accuracy of the aging technique, however, decreases with age. Some turtles estimated to be over 30 were impossible to age due either to excessive wear or flaking of the epidermis. In addition, some older turtles may cease growing, as suggested by Petokas (1986). Although plastral growth lines have been considered as annuli, and used widely in estimation of age in *E. blandingii* (Congdon and van Loben Sels 1991; Gibbons 1987; Graham and Doyle 1977; Petokas 1986; Ross 1989), indeterminate growth and consistent annulus formation in older adults have not been demonstrated. In Snapping Turtles, *C. serpentina*, about one half of adults fail to add visible carapacial annuli in successive years (Galbraith and Brooks 1987). Cessation of growth of some adults in our sample would result in under estimation of age of these individuals; the data presented are therefore minimum ages.

Sampling bias may account for the apparent paucity of juveniles in the Nova Scotia population. Scarcity of juveniles in sampled populations of *E. blandingii* is commonly reported (Congdon et al. 1983; Gibbons 1968; Graham and Doyle 1977; Weller 1973*; Ross 1989) and often attributed to behavioural differences or differential habitat usage by juveniles (Graham and Doyle 1977; Ross 1989). However, long-term studies in Michigan (Congdon et al. 1983) found no evidence of differential habitat use by juveniles.

In Nova Scotia, the under-representation of adult age classes 16-20 and 21-25 (0% and 6.1% respectively of the population) is troubling. Individuals in these two age classes are sexually mature and should be as visible as older adults. If this apparent absence is real, an unstable age structure in this population is indicated.

Reproductive Potential

At the population level, reproductive potential of Blanding's Turtle incorporates average annual reproductive output (number and size of eggs) per adult female, as well as subsequent egg and hatchling survivourship. At the individual level, especially for such a long-lived species, clutch frequency and reproductive lifespan, as well as clutch size, are essential to any consideration of reproductive potential. Annual reproductive output at both individual and population levels may be environmentally constrained (Gibbons et al. 1982).

In some populations of Blanding's Turtle, clutch and egg size increase with adult female size (Petokas 1986; MacCulloch and Weller 1988; Congdon and van Loben Sels 1991); in others, including the Nova Scotia population, the relationship is not clear (DePari et al. 1987; Power 1989). In addition, juvenile growth rates, rather than adult growth and longevity, largely determine adult size (Congdon and van Loben Sels 1991) and are therefore an important determinant of reproductive potential. Increased growth and body size in this species have been

attributed to increased habitat productivity (Graham and Doyle 1977; Petokas 1986; Ross 1989). However, even in productive habitats, growth may be constrained by competition for food, particularly where juvenile recruitment is high (Petokas 1986).

Although the environments occupied by Blanding's Turtle in Nova Scotia are relatively unproductive (Schell and Kerekes 1988*), body sizes of adults are within the range reported elsewhere (Gibbons 1968; Graham and Doyle 1979; Petokas and Alexander 1981; Congdon et al. 1983; Kofron and Schreiber 1985; Graham and Forsberg 1986; DePari et al. 1987; Rowe 1987; MacCulloch and Weller 1988; Ross 1989; Congdon and van Loben Sels 1991; Rowe 1992). As well, the mean clutch size of the species in Nova Scotia (9.4 eggs, range 1-15; Power 1989) falls within the range of mean clutch sizes (7.6-12.9 eggs) reported for other populations (Gibbons 1968; Congdon et al. 1983; Petokas 1986; DePari et al. 1987; MacCulloch and Weller 1988; Congdon and van Loben Sels 1991).

Clutch Frequency

Gibbons (1982) has suggested that since turtles are long-lived, clutch frequency is the most important parameter to measure in studies of reproduction. Blanding's Turtle produces a maximum of one clutch of eggs annually. In Michigan, only 23%-48% of females nested in a given year (Congdon et al. 1983). Although information for Nova Scotia is scant, two radio-tagged females nested in consecutive years (Power 1989). In addition, at least six of eight radio-tagged turtles nested in the same year (Power 1989). Although longer term data are required to obtain an accurate estimate of clutch frequency in Nova Scotia, indirect evidence suggests an individual may nest in at least two of three years.

Clutch Survivorship

In Nova Scotia only nine (69.2%) of thirteen nests protected from predation produced live hatchlings; the remaining four failed entirely, due to flooding in late summer (Power 1989). Among successful nests, egg failure (mean=3.1 eggs per nest) was higher than has been reported elsewhere (mean=1.2 eggs per nest; Congdon et al. 1983). Although long term data are not available for Nova Scotia, it appears that egg failure due to factors other than flooding and predation may be higher here. As well, flooding may be a major cause of nest failure in Nova Scotia in some years. This has not been reported elsewhere for Blanding's Turtle, although clutch failure in the Painted Turtle (*Chrysemys picta*) has been attributed to flooding of nests in early spring (Christens and Bider 1987).

Clutch Predation

Raccoons are the most important predators of eggs of Blanding's Turtle in Nova Scotia (Thexton and Mallet 1977-79*; Power 1989; Weller 1973*), although ants were suspected in at least one case (Weller 1973*). In a recent intensive investigation of nesting ecology of the species in Kejimkujik National Park, thirteen nests were protected with wire screening from predation by raccoons (Power 1989). Although no estimate of predation rate on the Nova Scotia population was possible, most protected nests showed signs of attempted predation, and it appeared that unprotected nests of all three species resident in the Park (Blanding's Turtle, Snapping Turtle, and Painted Turtle) were often destroyed on the night of oviposition (Power 1989). Outside Nova Scotia, predation rates on nests of Blanding's Turtle approached 100% in some years, with red foxes, ants (Congdon et al. 1983) and skunks (Petokas 1986) implicated, in addition to raccoons. Nesting habitat of the Nova Scotia population is distributed along edges (beaches, roadsides); predation rates in such linear habitats can be relatively high (Temple 1987).

Hatchling Survivorship

In addition to egg and clutch failure, many live hatchling Blanding's Turtles in Nova Scotia (16.1%) failed to emerge from nests by late fall (Power 1989). When nests were excavated at this time, these individuals appeared dormant. Although they probably would not have emerged had they been left undisturbed, their subsequent over-wintering success remains unknown. Over-wintering in the nest by hatchling Blanding's Turtles has not been documented, although indirect evidence (Congdon et al. 1983) suggests that it may occur rarely. Hatchling *C. picta*, which normally emerge in spring, are known to survive extended periods of subzero temperatures in the nest over winter (Storey et al. 1988; Packard et al. 1989). In some areas, however, freezing may be an important cause of mortality of *C. picta* hatchlings overwintering in nests, though deep snow effectively insulates hatchlings against freezing (Breitenbach et al. 1984). Submergence of nests of Blanding's Turtles on lakeshore beaches in late fall (Power 1989), which occurred in Nova Scotia in two consecutive years, may also protect hatchlings from freezing.

Reproductive Lifespan

Blanding's Turtle matures later and lives longer than most freshwater turtles. Sexual maturation occurs at about fourteen years in most populations (Graham and Doyle 1977; Petokas 1986; Congdon and van Loben Sels 1991), although in Wisconsin it may not occur until eighteen years (Ross 1989). Individuals frequently survive to thirty-five years in Illinois (Gibbons 1987), Nova Scotia (Herman et al. 1989*), and Michigan (Congdon and van Loben Sels 1991) and occasionally beyond seventy years (Brecke and Moriarty 1989; Herman et al. 1989*) with no evidence of reproductive senility. Based on these findings and observations of marked individual turtles

nesting in Kejimkujik National Park in multiple years, the reproductive lifespan of Blanding's Turtle in Nova Scotia should commonly exceed twenty years.

Species Movement

In Nova Scotia, capture-mark-recapture and radio-tracking revealed that Blanding's Turtles maintained three primary centres of activity on rivers and streams near the margin of Kejimkujik Lake (Figure 4) (Power 1989). These areas had also been generally identified during a long-term marking program in Kejimkujik National Park (1969-1982) (Weller 1973*; Bleakney 1976*; Thexton and Mallet 1977-79*; Drysdale 1983*). Although most turtles maintained a home range within one of these areas, at least three males shifted their range from one centre of activity to another, moving minimum distances of 5, 8.5, and 11.5 km overland (Herman et al. 1989*). One of these males moved a minimum of 3 km overland in less than fourteen days to establish residency in a different drainage.

In Nova Scotia, Blanding's Turtle became active in early April and generally moved downstream from overwintering areas by early May (Power 1989). Turtles on smaller streams moved to inflows of Kejimkujik Lake where most summertime activity was concentrated; on larger rivers turtles used the lake infrequently or not at all. Overwintering sites were usually located at the upstream margin of individual ranges. Onset of dormancy varied among individuals, but males generally entered hibernation later than did females.

On the basis of behavioural observations, four seasons of activity were recognized: post-emergence (early May-mid June), nesting (mid June-mid July), mating (mid July-mid November), and overwintering (mid November-late April). During post-emergence males made more long-distance (>1 km) movements than females; during nesting, females made more long-distance movements than males and travelled up to 2.9 km (straight line distance) to nest.

Home ranges of Blanding's Turtle in this population, exclusive of nesting migrations and apparent range shifts of males, frequently exceeded 1.5 km in at least one dimension (Power 1989). Nova Scotia turtles appear to be considerably more vagile (unpublished data) than has been reported elsewhere (Ross 1989; Ross and Anderson 1990; Rowe and Moll 1991). Physical barriers probably delimit both metapopulation and home range boundaries (Ross and Anderson 1990).

Adaptability

Among North American freshwater turtles, *Emydoidea blandingii* has one of the most latitudinally compressed ranges. Both the northern and southern limits of the species appear to be constrained by temperature. In addition, the species has one of the lowest critical thermal maxima (CTM) of any semi-aquatic turtle (Hutchison et al. 1966). In Nova Scotia, the population is restricted to an inland plateau characterised by the highest cumulative heat units in the province (Gates 1973*), and is considered to be a relict of a warmer climatic period (Bleakney 1958a). Therefore the species appears to have a relatively narrow range of temperature tolerance. This, in addition to the fragmented distribution of existing populations, suggests that the adaptability of the species is limited.

This limited physiological tolerance, in combination with long generation time (33-35 years; Herman et al. 1989*), limits the potential adaptive responses of Blanding's Turtle to environmental change. For example, measurable climatic change may occur within the lifetime of an individual turtle. Adaptive responses to such changes would thus have to be largely behavioural rather than genetic (Herman and Scott 1992). Although turtles in general are not noted for their behavioural plasticity, Blanding's Turtle has shown that it can adapt to locally changing availability of nesting substrate. This includes the use of artificial nesting sites both in Nova Scotia (Bleakney 1963; Weller 1973*; Thexton and Mallet 1977-79*; Drysdale 1983*; Power 1989; H. MacCormack, personal communication) and elsewhere (Graham and Doyle 1979; Petokas 1986; Breisch and Eckler 1988*; MacCulloch and Weller 1988).

Little information is available on genetic variation or structure in populations of *Emydoidea blandingii.* Turtles in general are notably invariant, based on allozyme studies (J. P. Bogart, personal communication). Although the Nova Scotia population is genetically isolated from all other populations, it in itself is probably panmictic. Although three discrete concentrations of turtles were identified in the Park, observations of promiscuous mating and long distance movements, especially by males, indicate that genetic exchange among them is probably sufficient to prevent divergence.

Special Significance of the Nova Scotia Population

The Kejimkujik population is the most isolated of all extant Blanding's Turtle populations. Small populations may undergo relatively rapid genetic change due to isolation, leading to genetic divergence. Although a limited electrophoretic survey of fifteen loci revealed no significant differences in frequencies and no alleles fixed at alternate loci between Nova Scotia and Ontario turtles, shell shape of both males and females differed significantly between the two populations (Eaton et al., submitted*). At this time we cannot confidently attribute this morphological distinctness to either environmental or genetic influences.

Cook (1987*) has stressed the need for protection of indigenous Canadian species that occur at the northern limit of their climatic tolerance. Bleakney

(1958a) observed striking differences in density among such peripheral populations, and documented the presence of isolated "islands" of herpetofauna along the northern edge of species' ranges. These inherently interesting but poorly studied populations provide a unique management challenge, particularly as they become further fragmented with changing land use or climate change.

Evaluation

Based on our morphometric analysis, the Nova Scotia population of *E. blandingii* can be considered morphologically distinct. In addition, the population is geographically distinct; i.e., obvious geographic barriers have prevented gene flow with other populations. This population is the sole representative of the species in the Atlantic Zone.

We recommend that the Nova Scotia population of Blanding's Turtle be assigned Threatened status for two major reasons: 1) the population occurs at the northeastern limit of the species range in a restricted area long isolated from other populations; and 2) the population is small and apparently declining: the age distribution is top-heavy i.e. unstable, and recruitment is low due partially to artificially increased predation pressure, primarily from raccoons.

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Home Range and Movements of the Common Snapping Turtle, *Chelydra serpentina serpentina*, in a Coastal Wetland of Hamilton Harbour, Lake Ontario, Canada

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Between June 1990 and August 1991, we radio-tracked the movements of 15 female and eight male Common Snapping Turtles (*Chelydra serpentina serpentina*) in a coastal wetland within Hamilton Harbour, Lake Ontario, Canada, to test whether these movements were predictable from differences in energy requirements and whether turtles that nested in a wetland, lived and fed in that wetland. The area and length of the home range and total distance travelled between observations were greater for female turtles than for males. Mean home range did not differ between 1990 (8.6 ha for females and 2.2 ha for males) and 1991 (9.7 ha for females and 3.4 ha for males) for either sex. The maximum distance travelled from the nesting site in 1990 was 2020 m. This was not measured in 1991. In 1990, but not in 1991, the distance travelled from the nesting site, the maximum length of the home range, and distances travelled between observations by females were positively and significantly related to their body mass. In both years, turtles moved the greatest distances from spring until mid-July and movement decreased throughout late July and August. Very little movement occurred between 31 August 1990 and 15 March 1991 when the turtles were hibernating. Following overwintering, turtles resumed movement after 15 March 1991. Male and female Snapping Turtles did not have significantly different home range sizes than turtles in previous studies of a more northern population in Ontario. However, nesting migrations were shorter for turtles from the Lake Ontario population probably due to greater availability of suitable nesting and feeding areas. Our findings indicate that home range size is not clearly correlated with expected differences in energetics requirements based on differences in habitat productivity, sex, or body size.

Key Words: Common Snapping Turtle, *Chelydra serpentina serpentina*, home range, movements, overwintering sites, Hamilton Harbour, Lake Ontario, Canada.

The Common Snapping Turtle, *Chelydra serpentina serpentina*, has often been described as sedentary (Cook 1984; Conant and Collins 1991), but few studies have quantified the movements of male and female Snapping Turtles or the factors that influence their movements. One northern population at Algonquin Park in Canada has been studied extensively. In that population, female Snapping Turtles had well defined annual nesting migrations (Obbard and Brooks 1980), whereas males tended to be more sedentary and to have greater fidelity to their home ranges (Obbard and Brooks 1981). Nevertheless, sizes of home ranges were not significantly different between males and females (Obbard and Brooks 1981; Brown 1992). Home ranges in males in this population varied among lakes (Brown 1992), but were consistent for individuals among years in both size and location (Galbraith et al. 1987).

It has been suggested that size of home ranges of Snapping Turtles may be negatively correlated with density (Galbraith et al. 1987; Brown 1992). The site of the present study, Cootes Paradise, a wetland connected to Hamilton Harbour on Lake Ontario, has a much higher density of Snapping Turtles than the Algonquin Park site (Galbraith et al. 1988). A eutrophic wetland such as Cootes Paradise may provide more food than the oligotrophic and dystrophic lakes in Algonquin Park. If size of home range is determined by food abundance, then we would predict that home ranges of turtles in the Cootes Paradise population should be smaller than those in the Algonquin Park population. Similarly, we predicted that there would be a positive correlation between body mass and size of home range because larger turtles would have greater energy requirements.

Although food availability may be important, there are other habitat differences between Cootes Paradise and Algonquin Park which may influence Snapping Turtle movements. For example, Cootes Paradise and Algonquin Park are very different in geology. Cootes Paradise is located in the Great Lakes Lowlands with thick deposits of sandy loam soil on its shores and easily accessible nesting sites, whereas Algonquin Park is located on the Canadian Shield with thin soil and few suitable nesting areas.

Given that nest sites should be more readily available around the Great Lakes lowlands, we predicted that female Snapping Turtles would travel shorter distances to nest in Cootes Paradise than in Algonquin Park. As well, these sites are located in very different climatic zones (Thaler and Plowright 1973) and little is known about how weather affects Snapping Turtle movements or if climatic differences affect size of home range.

Furthermore, because Snapping Turtle eggs have been recommended as a monitor of local contamination in wetlands by a number of authors (Stone *et al.* 1980; Ryan et al. 1986; Struger et al. 1993) and contaminants have been detected in Snapping Turtle eggs from Cootes Paradise, this study investigated the movement of nesting Snapping Turtles in Cootes Paradise to be sure that turtles sampled for future analysis of contamination at a local nesting site lived and fed within the wetland. We also report on home range use, movement patterns, and the characteristics of overwintering sites used in this study area.

Study Area

The study took place in Cootes Paradise, a 45-ha eutrophic wetland (Semkin et al. 1976) within the boundaries of the Royal Botanical Gardens in Hamilton, Ontario, Canada (Figure 1). This wetland constitutes the most westerly end of Lake Ontario and is connected to Hamilton Harbour. Primary species of aquatic vegetation in the wetland are: Broad-leafed Cattail (*Typha latifolia*), European Manna Grass (*Glycera maxima*), rushes (*Scirpa* sp.), and willows (*Salix* sp.) (Galbraith et al. 1988). Carp (*Cyprinus carpio*) are abundant and other common aquatic vertebrates include bullheads (*Ictalurus* sp.), Midland Painted Turtles (*Chrysemys picta marginata*), and Snapping Turtles (Galbraith et al. 1988). A large number of fish migrate into Cootes Paradise from Lake Ontario during spring through to early July and fish density is highest during those months (C. Portt and V. Cairns, unpublished). Cootes Paradise' Snapping Turtles and their eggs are contaminated with chlorinated hydrocarbons (Bishop et al. 1991; Struger et al. 1993).

Materials and Methods

Between 7 and 9 June 1990, 16 female Snapping Turtles were caught on land immediately after nesting and approximately 100 m from West Pond (Figure 1). On 26-27 June 1990 and 29 May - 6 June 1991, eight male turtles (four each year) were captured in West Pond using hoop net traps baited with dead fish (Figure 1). Each captured turtle was given a unique identity number by notching of the carapace (Cagle 1939) and tagged with a radio transmitter (172 MHz; Lotek Engineering, Aurora, Ontario, or Holohil Systems, Woodlawn, Ontario). Transmitters weighed 30 g and were 8 × 2 × 1 cm with a 15 cm whip antenna. Transmitters were attached to the posterior marginal scutes of the carapace using 2.5 cm stainless steel bolts and nuts inserted through holes drilled with a hand drill. Transmitter battery life was 18-24 months. The receiving antenna was a 4-element unidirectional yagi model with coaxial cable attachment. All tagged turtles were released at their capture site within 24 h.

From 15 June to 30 August 1990, each turtle was sought five times per week, once per day on three days, and morning and evening on one other day. After 1 September 1990, the turtles were sought approximately monthly until April 1991; after which the turtles were sought twice per week until 31 August 1991. If a turtle could not be located within the wetland, numerous attempts were made to locate it in Hamilton Harbour, in Lake Ontario, and in surrounding waterways.

Sightings were recorded, within approximately 5 m of the turtle's exact location, onto enlarged copies of the Ontario Base maps (1: 2 000). This information was transferred to Ontario Base maps (1:10 000; Ontario Ministry of Natural Resources 1984) using a proportional grid to aid in exact copying. Distances travelled each week (Friday to Friday) were calculated by summing minimum (straight-line) distances between successive fixes assuming that turtles always travelled in water. Home range areas were calculated by the modified minimum area method (Harvey and Barbour 1965) using a compensating polar planimeter. Any sighting more than one fourth the length of the home range (including that location) from the next closest was not used to calculate the area of the home range (Harvey and Barbour 1965). Terrestrial habitat was not included in the calculation of either home range area or travel distances because, other than during nesting, no Snapping Turtle was seen or found on land during the study. Upon visual inspection of the resulting home range area, groups of several sightings for the turtle were noted as "centres of activity" (Kenward 1987).

We calculated maximum length of home range (m) (excluding migrations to the nesting or wintering site), and home range area (ha). Correlations of these measurements with body mass (kg) among all individuals and among females were tested using Pearson's rank coefficients. No tests were performed to examine the relationship between mass of male turtles and distance travelled because of small sample size. Relationships between sex and movement variables were tested using Friedman's statistic (Sokal and Rohlf 1981; SAS 1988a). Mean areas and maximum lengths of home range were compared between years for each sex using Student's (for equal variances) or Satterthwaite's (for unequal variances) T-test. Travel distances were compared among weeks and among individual turtles using

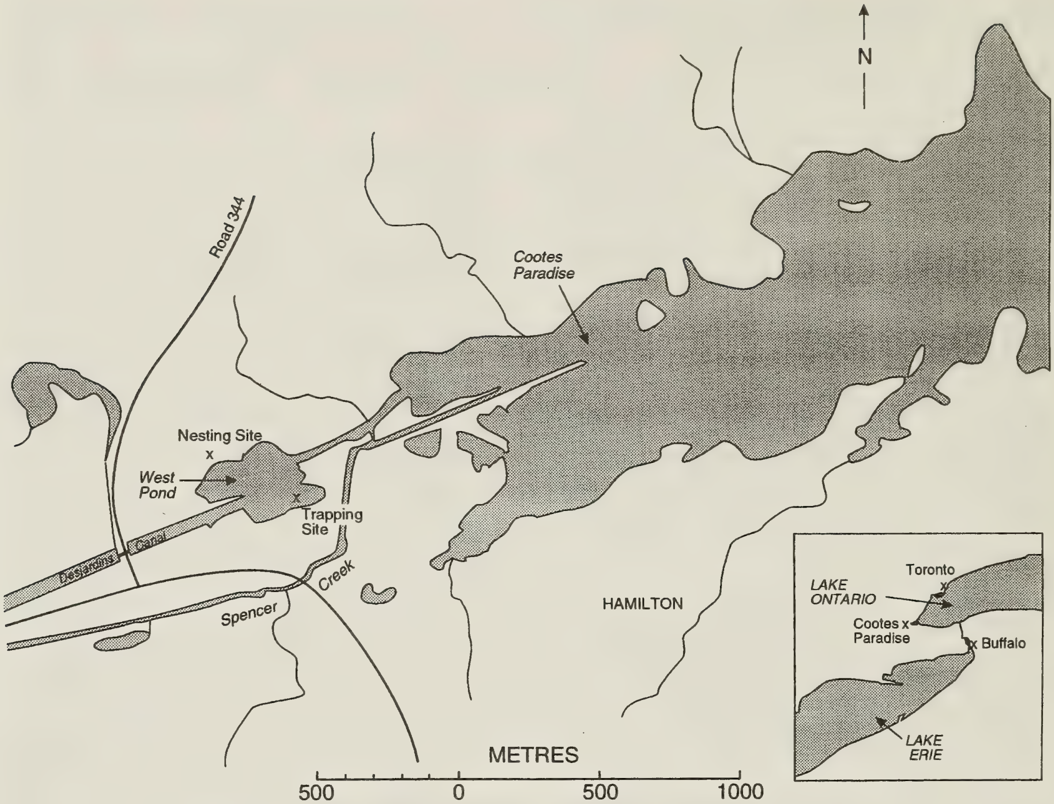

Figure 1. Location of Cootes Paradise, Ontario (inset - western Lake Ontario).

ANOVA, and compared between years and sexes using Cochran's T-test (Sokal and Rohlf 1981; SAS 1988b). The level of significance was set at $p \leq 0.05$ for all statistical tests.

Results

Home Range

In 1990, 19 turtles (15 females and 4 males) were located by radio-telemetry from 23 to 57 times. In 1991, 13 turtles (7 females and 6 males) were located from 25 to 40 times. One transmitter stopped functioning immediately after the turtle was released in 1990. Ten transmitters stopped functioning or fell off the turtle as the study progressed.

In 1990, home range areas varied from 1.0 to 28.4 ha. Home ranges of females were generally larger than males with mean area of 8.5 ± 7.8 (S.D.) ha for females and mean area of 2.3 ± 1.3 ha for males ($T = 2.9656$, $p < 0.01$, df = 16, variances unequal). In 1991, home range areas varied from 1.0 to 22.0 ha. Home ranges of females were larger than males with mean area of 9.7 ± 6.2 ha for females and mean area of 3.4 ± 2.2 ha for males ($T = 2.5070$, $p < 0.05$, df = 7, variances unequal). There was no difference between the mean home range area in 1990 and 1991 for either sex (♀: $T = -0.3$, $p > 0.05$, df = 20; ♂: $T = -0.9$, $p > 0.05$, df = 8).

In both years, individual turtles displayed one of three types of home range: a single centre of activity, two - four centres of activity, or no definable centre of activity. All activity centres for males were well defined. The ratios of home range types among female turtles were 6 (single centre of activity) : 6 (multiple centre of activity) : 3 (no centre of activity) in 1990, and 4:2:1 in 1991. For the males, the ratios were 3 (single centre of activity) : 1 (multiple centre of activity) : 0 (no centre of activity) in 1990, and 3:3:0 in 1991. Of those with single centres of activity in 1990, two male and three female turtles stayed in West Pond from nesting through wintering inclusive, and one male and three females moved from West Pond after the nesting season to occupy fairly local home ranges elsewhere (Figure 2). One male and six females maintained multiple activity centres in 1990 which included areas within and outside of West Pond (Figure 2). Three females moved around without defined centres of activity in 1990 (Figure 3). Of seven females and two males tracked in both years, all maintained their original home range type, except one male. This male had a single centre of activity

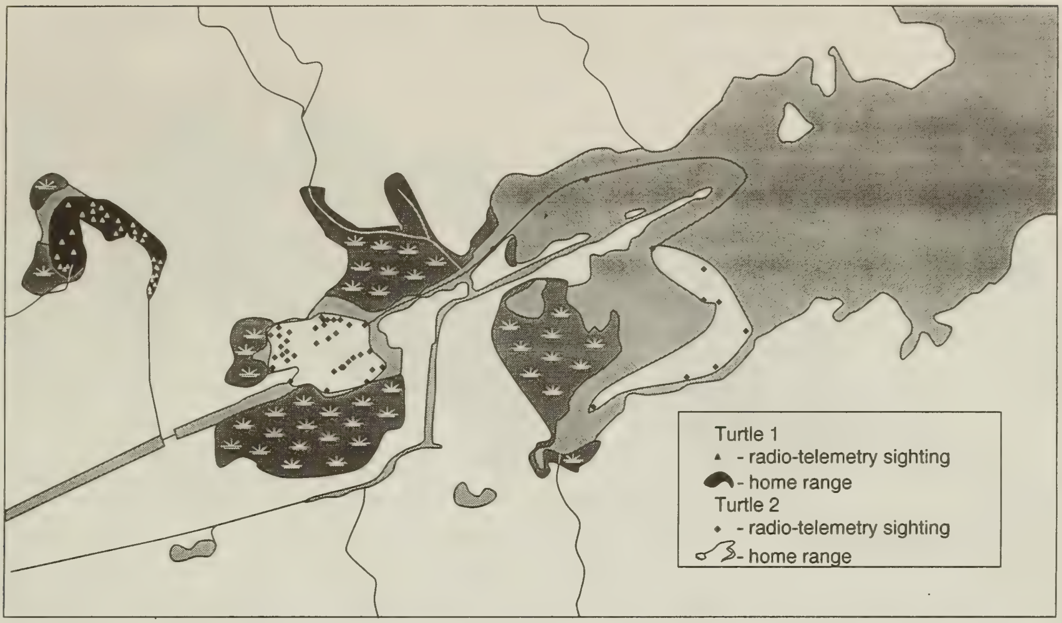

Figure 2. Examples of home ranges of female Snapping Turtles with a single (Turtle 1) and with multiple centres of activity (Turtle 2) in Cootes Paradise, Ontario, 1990.

outside of West Pond in 1990, returned to West Pond on 10 May 1991, then returned to the area used in 1990 on 12 July 1991 and stayed there for the rest of the summer. Thus, he switched from a single centre to two centres of activity. This may have been an artifact of the date of capture (late June) in 1990 rather than an actual change of habit by the turtle.

Distance Travelled

In 1990, the maximum distance recorded for female turtles away from the nesting site was 370 to 2020 m ($\bar{x}$ = 1053 ± 529 m, N = 15). The maximum length of the home range excluding migrations in one summer by any radio-tagged turtle in 1990 was 2020 m and the minimum was 340 m. In 1991, length of tagged turtles' home range varied from 280 m to 1740 m. There was no significant difference between the mean length of home range in 1990 and 1991 for either sex (♀: T = 0.5, $p > 0.05$; ♂: T = -0.3, $p > 0.05$).

During June - 31 August 1990, the distance travelled within any given week was 0 to 3730 m. Total distance travelled between all observations made during June - 31 August 1990 ranged from 2490 m to 10770 m by females and ranged from 1210 m to 3670 m for males. Significant differences in total distance travelled between sightings existed among turtles ($p = 0.0001$, $r^2 = 0.25$) and among weeks ($p = 0.0001$, $r^2 = 0.35$) during June - August 31 1990. Female turtles travelled significantly more per week ($\bar{x}$ = 588 ± 607 m) than males ($\bar{x}$ = 209 ± 235 m) (T = 6.28, $p = 0.0001$, df = 143).

During June - 31 August 31 1991, the distance travelled within any given week was 0 to 2080 m. Total distance travelled between observations ranged from 950 m to 8650 m for females and ranged from 1060 m to 2520 m for males. Significant differences in total distances travelled between sightings existed among turtles ($p = 0.0001$, $r^2 = 0.26$) but not among weeks ($p > 0.05$) during June - 31 August 1991. Female turtles travelled significantly more per week ($\bar{x}$ = 361 ± 451 m) than males ($\bar{x}$ = 149 ± 191 m) (T = 3.95, $p = 0.0002$, df = 124).

In 1990, individual turtles moved significantly more each week ($\bar{x}$ = 523 ± 579 m) than in 1991 ($\bar{x}$ = 271 ± 378 m) (T = 5.03, $p = 0.0001$, df = 358). Female turtles moved significantly more each week in 1990 ($\bar{x}$ = 587 ± 607 m) than in 1991 ($\bar{x}$ = 361 ± 451 m) (T = 3.42, $p = 0.0009$, df = 224). However there was no significant difference between 1990 ($\bar{x}$ = 209 ± 235) and 1991 ($\bar{x}$ = 149 ± 191) in distances recorded each week for males (T = 1.32, $p > 0.05$, df = 61).

Snapping Turtles moved the greatest distance and most frequently during June until the second week of July (Weeks 1-7, Table 1). The frequency of movement and total distance moved decreased toward the end of July and turtles moved very little during August (Weeks 10-13, Table 1). Three turtles did not move to their final overwintering site until October or November. No turtle moved after 15 November. Movement began again between 7 March and 7 April 1991 for 10 turtles, but five turtles located in

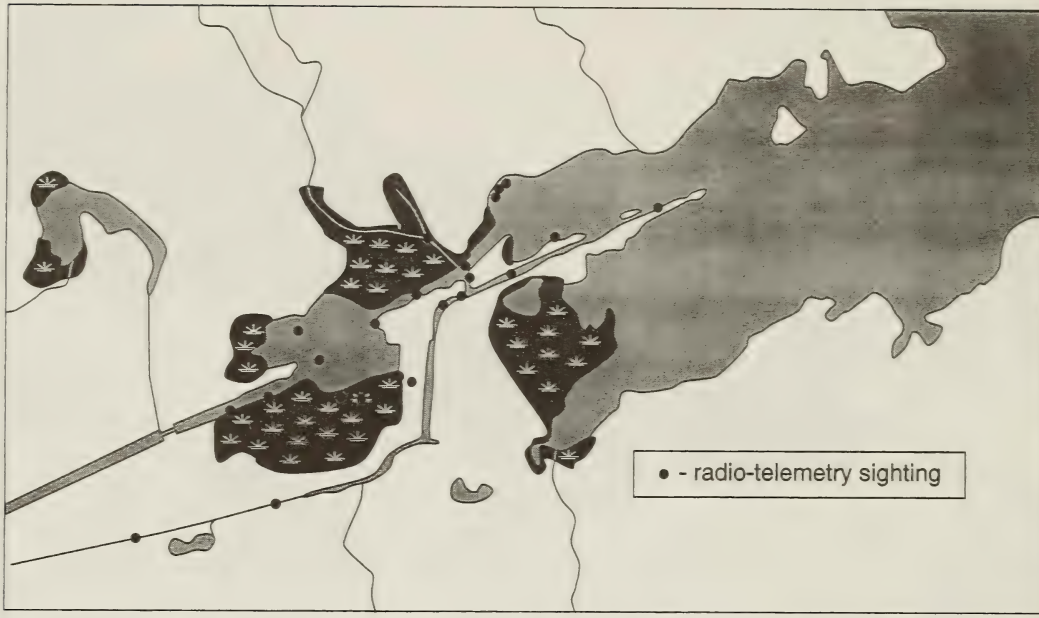

Figure 3. Telemetry sightings of a female Snapping Turtle with no discernible centres of activity in Cootes Paradise, Ontario, 1990.

areas that were still frozen in March had not moved by 7 April 1991.

Body Mass and Distance Travelled

At capture, mass of female turtles ranged from 2.6 to 8.1 kg ($\bar{x}$ = 5.5 kg, N = 15), and male mass ranged from 4.95 to 13.26 kg ($\bar{x}$ = 8.2 kg, N = 8). Body mass of female turtles at capture was significantly and positively correlated in 1990 to maximum distance travelled away from the nesting site ($p = 0.02$, $R_p = 0.58$), maximum home range length ($p = 0.04$, $R_p = 0.54$), and total distance travelled from sighting to sighting ($p = 0.04$, $R_p = 0.51$). When males were included in the analysis, correlations between body mass and home range length or total distance moved between sightings were not significant ($p > 0.05$, N = 19).

Wintering Sites

Wintering sites varied in their physical characteristics. Two male and two female turtles spent the winter as a group under the bank of a point of land which was heavily undercut with Muskrat (*Ondatra zibethica*) tunnels (Figure 4). Another male overwintered under a creek bank with several untagged turtles (Figure 4). Both of these overwintering sites were on the banks of open moving water (Desjardins Canal and Hopkin's Creek) (Figure 1). Two females were found separately in West Pond, more than 10 m from the shoreline, in open water from 0.3 - 0.5 m deep (Figure 4). Of those, one was within 2 m of the path of a stream emptying into West Pond. One male and one female overwintered in shallow marshes, buried in mud beneath fallen logs; the male was located near running water (Figure 4). Another female was located under fallen logs which formed a dam across a creek, and where the water was moving (Figure 4). Five female turtles were located in separate shallow weedy areas and no untagged turtles were found nearby (Figure 4).

Discussion

Home ranges of female Snapping Turtles were larger than those of males in Cootes Paradise, whereas in Algonquin Park, Snapping Turtles showed no significant difference in size of home range between the sexes (Obbard and Brooks 1981; Brown 1992). Sizes of male home ranges were similar between Cootes Paradise and Algonquin Park values reported by Obbard and Brooks (1981) and Brown (1992), but larger than values reported by Galbraith et al. (1987) ($T = 3.80$, df = 10, $p < 0.01$). However, in Algonquin Park, size of home range varied up to an order of magnitude among turtles in different lakes (Brown 1992) and the lake studied by Galbraith et al. (1987) had the smallest home ranges. Size of home range of females in Cootes was larger than that reported by Obbard and Brooks (1981) ($T = 3.05$, df = 23, $p < 0.01$), but was virtually identical to values reported by Brown (1992) and Brown et al. (1994).

Home range of an animal is presumably related to the spatial and temporal distribution of key resources, and we would expect that variation in size of the

Table 1. Total distance travelled between radio-telemetry observations of Snapping Turtles in Cootes Paradise, Ontario during 7 June-31 August 1990 and 1991

Females													
1990													
Week	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean	458	520	556	957	786	1438	582	673	345	191	95	220	188
S.D.	554	556	294	499	506	951	428	544	333	251	130	220	262
N	14	14	14	14	14	14	15	15	14	14	11	11	11
1991													
Week	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean	560	479	462	237	203	563	270	355	413	165	394	107	396
S.D.	359	424	517	215	83	596	213	439	472	223	563	99	693
N	7	7	9	7	6	6	7	6	7	6	7	6	7
Males													
1990													
Week	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean					248	623	113	313	238	73	68	138	73
S.D.					71	258	97	193	147	22	117	238	126
N	0	0	0	0	4	4	4	4	4	4	4	4	4
1991													
Week	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean	263	255	123	238	127	170	167	175	193	185	187	197	194
S.D.	153	164	108	101	200	238	236	230	229	227	224	229	228
N	4	4	6	6	5	5	5	5	5	5	5	5	5

home range and an animal's pattern of use of its home range would reflect this relationship. The key resources usually associated with variation in size of home range are food, density and shelter. The similarity in size of home ranges of turtles in Cootes Paradise to those of turtles in Algonquin Park is remarkable given the great differences in productivity and in density of Snapping Turtles between sites (Galbraith et al. 1988; Brown et al. 1994). Home range sizes of Algonquin Park turtles were larger in the late 1980s than those of the same population in the 1970s. Brown (1992) speculated that these differences may have been the result of a marked decline in density. Broadwing Pond in Algonquin Park is similar in size and depth to West Pond in Cootes Paradise, but is much less productive and has a much lower density of turtles (Galbraith et al. 1988). Nevertheless, home ranges of turtles are smaller in Broadwing Pond than those in Cootes Paradise (Galbraith et al. 1987) and also smaller than home ranges in other lakes studied in Algonquin Park.

Size of home range was not consistently correlated with turtle body size in our study. As well, female turtles had larger home ranges, yet were smaller in body size than were male turtles. In Algonquin Park, neither sex nor body size had any significant effects on the size of home range (Obbard and Brooks 1981; Brown 1992). Taken together, the above findings suggest that none of density, body size, sex, or primary productivity play an important role in determining size of home range in Snapping Turtles. Home range size may be independent of foraging requirements, at least independent enough that our measures of home range may be too crude to elucidate the relationship. Similarly, differences in energy requirement between the sexes or among turtles of different size are not reflected in measures of home range size made with current methodologies. Of course, it may still be true that food availability is an important determinant of home range size but that different turtles forage on different resources (Brown 1992) and hence obscure the relationship between size of home range and energy requirements.

Alternately, Snapping Turtles may respond to increased food resources by simply growing faster, and increasing density and reproductive output (Brown et al. 1994), but not by changing the size of the home range. Clearly, more detailed knowledge of energy budgets and movements are required, or perhaps even a new approach to the significance of home range dynamics on relatively sedentary ectotherms like turtles.

Rates of digestive turnover in Slider Turtles (*Trachemys scripta*) increase with increasing temperature (Parmenter 1981). It has been suggested by

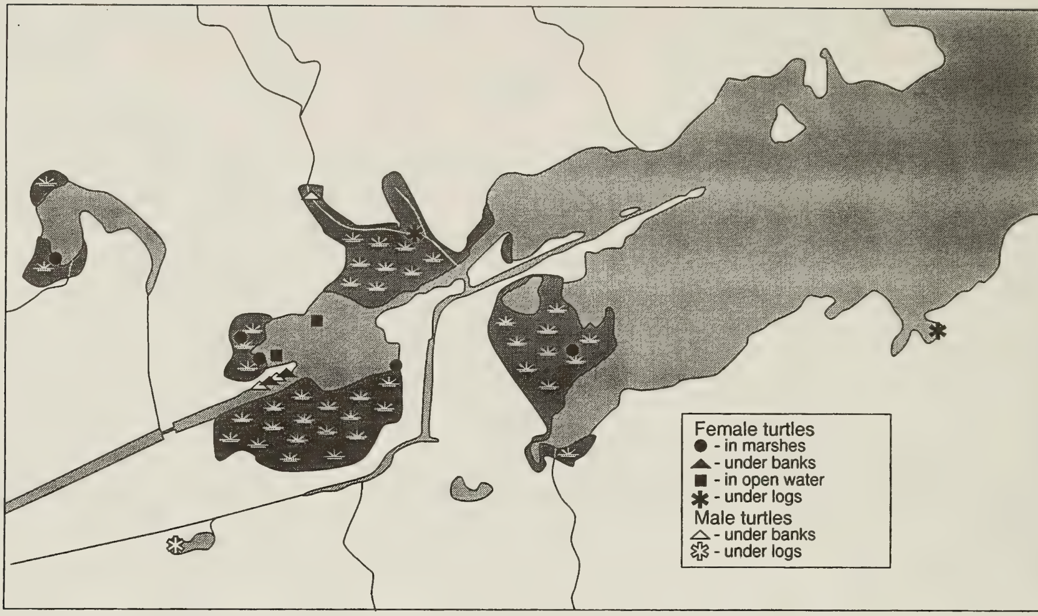

Figure 4. Wintering sites of 11 female and 4 male Snapping Turtles as determined by radio-telemetry in the current study at Cootes Paradise, Ontario, 1990–1991.

Brown (1992) that Snapping Turtles in Algonquin Park, in an environment of low primary production, maintain a lower metabolism to conserve energy and depress food needs. Snapping Turtles in Algonquin Park spend a great deal of time at temperatures lower than those preferred in a laboratory setting (Brown et al. 1990; Brown and Brooks 1991). Feeding activity of Slider Turtles is stimulated by elevated temperatures in the laboratory (Parmenter 1980). It is possible that Snapping Turtles in Cootes Paradise may be eating more, and, therefore, foraging more despite eutrophic conditions because the water tends to be warmer (Galbraith et al. 1988; Brown et al. 1994).

Snapping Turtles eat a wide variety of foods including aquatic plants, insect larvae, fish, and carrion (Alexander 1943; Lagler 1943). Some studies of the gut contents of Snapping Turtles have shown that up to 60% of their diet can be made up of aquatic and semi-aquatic plants (Alexander 1943). The Algonquin Provincial Park site has abundant aquatic and semi-aquatic vegetation (Obbard and Brooks 1981) whereas Cootes Paradise does not. Cootes Paradise contains many large, slow moving fishes and regular migrations of spawning Lake Ontario fishes which may provide more abundant food resources to the foraging turtle. The question is: how do different resources and foraging patterns affect home range and movements? Generally, vegetation is less nutritious than animal food and herbivorous species or populations of turtles grow more slowly than carnivorous ones (Gibbons 1967; Hart 1982; MacCullogh and Secoy 1983).

It is well documented that Snapping Turtles exhibit intraspecific aggression (Hammer 1971; Froese and Burghardt 1975; Tyning 1990). Pell (1941) states that he was only once able to trap more than a single turtle in a single location, and then only after an interval of one week. However, in Cootes Paradise, many turtles are often caught in the same location, often in the same trap, but this rarely occurs in Algonquin Park and when it does male turtles injure one another, often severely (authors' unpublished data). Galbraith et al. (1987) suggest that, for males, avoidance of other turtles may be due to aggressive interaction. Territoriality is an attractive explanation for the relative consistency of home range size in males, but this argument is suspect because although males are vigorously aggressive toward one another, they don't appear to be territorial (Galbraith et al. 1987).

Nesting migration distances in Cootes Paradise are comparable to those found in South Dakota (Hammer 1969) and in southeastern Michigan (Congdon et al. 1987), and tend to be much shorter than those of the more northern population in Algonquin Park (Obbard and Brooks 1980). In Algonquin Park, nesting migrations often represent the only excursions into the area of the major nesting site on a gravel dam. This demonstrates that the geography of the Canadian Shield, when compared to that of the Great Lakes shoreline, probably has an

effect on the availability of suitable nesting sites close to the foraging range. As evidenced by the short migration distances, turtles nesting on the shores of this wetland live and feed within the wetland, and contaminants in their eggs are acquired within the wetland; therefore, they are a suitable indicator of local contamination of this wetland.

Winter sites chosen by turtles in this study were similar to those in previous studies (Ernst and Barbour 1972; Obbard and Brooks 1981; Meeks and Ultsch 1990; Brown and Brooks 1994). However, some turtles in this study spent the winter in open water of approximately 0.5 m depth, thus not fulfilling all of the requirements postulated by Meeks and Ultsch (1990). Some turtles moved into and out of overwintering sites throughout the summer suggesting that these sites have value to the turtles all year long. This is indirectly supported by the fact that there are often several turtles found in a single site at Cootes Paradise and elsewhere (Meeks and Ultsch 1990; Brown and Brooks 1994).

Although home range is a widely used and recognized concept, it continues to be difficult to represent the home range so that it reflects biologically and ecologically relevant constraints because most models are highly constrained by their simple mathematics (Kenward 1987). As well, size, shape, and orientation by themselves can tell us little about the animals' ecology (Don and Rennolls 1983). Most models are based on a concept of the home range as having a geometric centre of activity with declining probability of encountering the animal as one moves further from the centre, thus describing circles or ellipses of probability (Calhoun and Casby 1958; Jennrich and Turner 1969). Models that allow for clumping of data produce better fits by not including large areas of home range not used by the animals (Kenward 1987). A more difficult problem occurs when animals, such as many of the Cootes Paradise Snapping Turtles, have more than one centre of activity (Don and Rennolls 1983). There are techniques for dealing with multiple "centres" of activity by viewing the home ranges as multilinear probability polygons and analyzing them with two-dimensional cluster analysis (Kenward 1987). The problem is that although these centres may reflect different activities or sources of resources, we do not know exactly what our turtles were doing within these areas or why they were used. Therefore, cluster analysis or harmonic mean models (Kenward 1987) may provide relatively more accurate and precise measures of size and shape of home ranges, but this is pointless when we don't know how to interpret them in terms of related biological phenomena. We can know that some areas are a resource for hibernation or nesting, but we are uncertain of the biological relevance of locations in between (but see Brown and Brooks 1993). Even more sophisticated treatments using three-dimensional models (Samuel et al. 1985) cannot tell us much more unless the patterns of use are tied to biologically relevant resources and events (Galbraith et al. 1987). For example, in Algonquin Park some, but not all, female Snapping Turtles have multiple centres of activity in a given year, but may or may not use these the next year (Brown 1992). Thus, there is annual temporal variation underlying the multiannual variation. Future research on turtle activity and movements should focus on identifying factors that determine focal areas of activity.

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Effects of Cottage Development on White-tailed Deer, *Odocoileus virginianus*, Winter Habitat on Lake Muskoka, Ontario

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We studied the effects of cottage development on the food and cover characteristics of winter habitat of White-tailed Deer (*Odocoileus virginianus*) on Lake Muskoka in 1989. Forest canopy characteristics (canopy closure and size of gaps) and browse supply were measured and contrasted with data collected on sites with cottage development and sites with no development. The canopy closure of conifers was greater on undeveloped sites than on developed sites. Openings in the shoreline fringe of conifer cover on developed sites did not show increased forage production typical of openings in forests because cottagers removed underbrush and established lawns. Winter browse supply was four times lower on developed cottage lots than on undeveloped shoreline sites. Cottage development reduced the carrying capacity for deer by lowering food supply and thermal cover provided by mature conifer trees. Cottage development which minimizes removal of conifers and underbrush from the shoreline fringe will minimize the impact of development on deer habitat.

Key Words: White-tailed Deer, *Odocoileus virginianus*, habitat, biomass, browse, canopy closure, development, Lake Muskoka, Ontario.

In central Ontario, deer concentrate during the winter months in traditional yarding areas characterized by conifers in the forest. Conifers intercept snow and thus improve mobility of deer and access to food (Hepburn 1959; Verme 1966; Ozoga 1968; Hanley and Rose 1987). In addition, the overhead cover reduces energy loss during cold weather (Moen 1968, 1976). Deer establish night-bedding sites and travel lanes in areas of conifer cover (Armstrong et al. 1983) and usually restrict their foraging activities to within 30-40 m of cover (Huot 1974; Wetzel at al. 1975; Voigt 1992). In many areas, conifer forest that occurs along the shorelines of lakes and rivers provides habitat for winter concentrations. Deer can move easily along wind-swept ice-covered shorelines but avoid travelling in open areas or deciduous forest when snow depths exceed 50 cm.

According to Armstrong et al. (1983) "the net effect of shoreline development is to fragment the continuity of the coniferous fringe, thereby reducing its value as habitat for travel lanes and night bedding". Shoreline development for cottages can potentially modify the conifer fringe by decreasing crown closure, creating gaps or openings, removing understorey and planting of species not available to deer during snow cover months. The effect of cottage development on forage supplies and forest canopy has not been quantified. If cottage development reduces conifer cover then there could be an increase in browse production since openings in the forest canopy allow sunlight to reach the forest understorey thereby increasing plant productivity (Behrend and Patric 1969). This effect could result in a potentially significant increase in forage supply provided cottagers do not remove the understorey plants released by the increased light levels. However, removal of canopy cover would increase energy costs for deer in winter and this loss of shelter may not be compensated by an increase in browse availability.

The purpose of this study was to determine differences in forest canopy and browse supply in the shoreline conifer fringe between sites with cottage development and no development. Objectives were to estimate the biomass of winter forage available to deer in undeveloped shoreline habitats and the conifer fringe and adjacent upland deciduous habitat; to estimate biomass in the conifer fringe on cottage lots showing high development and lots showing low development; to estimate biomass immediately adjacent to cottages on lots with high and low development. We also measured canopy closure and gap size created by cottage development as an index to the energy costs for deer during winter.

Study Area and Methods

Shoreline areas used by wintering deer on Lake Muskoka (45°00′N, 79°30′W) were sampled for deer winter food and cover on 5 and 6 July 1989. Lake Muskoka is located in the Great Lakes St. Lawrence forest region and is surrounded by extensive upland deciduous forests of Sugar Maple (*Acer saccharum*), American Beech (*Fagus grandifolia*) and White Birch (*Betula papyrifera*). Conifer forests especially near shorelines are of Eastern White

Cedar (*Thuja occidentalis*), Eastern Hemlock (*Tsuga canadensis*), Eastern White Pine (*Pinus strobus*), Red Pine (*Pinus resinosa*) and Balsam Fir (*Abies balsamea*) (Rowe 1972).

Cottage lots were divided into three categories: no development, low development, and high development. High development lots were characterized by an opening or gap in the conifer fringe within 45 m of the shoreline and extensive disturbance to the forest understorey due to clearing or grass planting. Low development lots were characterized by little disturbance to the conifer forest overstory and natural vegetation in the understorey. Eight lots from each development category were sampled.

We sampled the conifer shoreline fringe at all lots. At undeveloped lots we also sampled upland deciduous habitat and at lots with cottages we sampled immediately adjacent to the cottage. Thus, the six habitats sampled were: undeveloped conifer shoreline; undeveloped upland deciduous forest; high development cottage site; low development cottage site; high development conifer shoreline fringe; and low development conifer shoreline fringe.

Plots located a minimum of 5 m apart were randomly positioned on transects oriented perpendicular to the shoreline. At the lots with cottages, five sample plots were randomly positioned along a 45 m transect placed through the middle of the cottage. Five sample plots were also chosen from two 20-m transects located 30 m on each side of the cottage transect. At undeveloped sites, five sample plots were randomly positioned along two 20-m transects 60 m apart located in the shoreline conifer fringe. An additional five plots were sampled from two 20 m transects located in deciduous forest on extensions of the conifer fringe transects.

At each plot a 2 × 2 m quadrat was randomly placed left or right of the transect. The number of twigs of current annual growth (>2.5 cm long) of woody plants originating in each quadrat between 50 cm and 200 cm above ground was tallied. Twigs were tallied as deciduous, Eastern Hemlock, White Cedar, White Pine or Canada Yew (*Taxus canadensis*). Other pines, spruces (*Picea* spp.), and Balsam Fir were not tallied as deer food.

At the undeveloped conifer and deciduous plots, all twigs of current annual growth (> 2.5 cm) were clipped. A random sample of twigs in each class (deciduous, White Pine, etc.) was weighed after oven-drying at 80°C for 48 hours. Average twig weights for each category were used to convert twig count data to estimates of forage biomass (kg/ha).

Forest canopy closure was estimated visually under current summer conditions. Conifer canopy closure was estimated to approximate canopy closure in the winter. At high and low development cottage sites we estimated gap size (m^2) in the canopy by noting their length and width.

The weight of forage per site was summed and ranked to provide an estimate for each lot. The Kruskal-Wallis test (Hollander and Wolfe 1973) was applied to ranked data to assess differences in browse availability among habitats since the amount of forage per plot was not normally distributed. Differences in canopy closure among habitats were tested using ANOVA and Duncan's Multiple Range test (Steel and Torrie 1980). The results of statistical tests were considered significant when $P \leq 0.05$.

Results

Winter deer food was distributed in patches. The percentage of plots with no deciduous browse was high for all habitats except upland deciduous forests (75-83% vs 23%). The biomass of deciduous browse was not different for all habitats except upland deciduous which was significantly higher ($P < 0.05$). Occurrence of conifer browse on plots was low (5-18%) for all habitats except undeveloped conifer forest (33%). When conifer forage occurred on a plot as White Cedar, Eastern Hemlock or White Pine, biomass estimates were markedly elevated resulting in a bimodal distribution of food per plot. The biomass

TABLE 1. Winter deer browse biomass and canopy closure for six habitats on Lake Muskoka, Ontario.

Habitat Type	n	Biomass (kg/ha)	Winter Canopy Closure[1] (%)	Summer Canopy Closure[2] (%)
Undeveloped Conifer Shoreline	39	24[3]	64	80
Undeveloped Upland Deciduous	40	22	6	78
Low Development Cottage Sites	40	5	37	62
High Development Conifer Shoreline	40	5	47	65
Low Development Conifer Shoreline	40	3	44	83
High Development Cottage Sites	40	2	13	26

[1]Canopy closure of conifer species only
[2]Canopy closure of all tree species in forest canopy
[3]With 1 outlier removed, > 3 SD from $\bar{x}$

biomass of conifer browse in all habitats was not different except for the higher biomass in undeveloped conifer ($P < 0.05$).

Differences occurred among habitats in the total biomass of deciduous and coniferous browse ($P < 0.05$). Biomass was the same for the undeveloped upland and conifer habitats (Table 1). Other habitats had lower quantities of browse.

Forest canopy closure was highest on undeveloped sites and lowest around high development cottage lots. Conifer canopy closure was low on deciduous sites and high development sites. The gap in the canopy created by clearing around high development cottage lots (2125 ± 837 m^2, $\bar{x} \pm 1$ SD) was considerably larger than for low development lots (747 ± 294 m^2, $\bar{x} \pm 1$ SD) ($P < 0.05$). For a standardized lot with a frontage of 60 m and a depth of 60 m, gaps comprised 56% of area of the high development lots but only 19% of the low development lots.

Discussion

Cottage development on Lake Muskoka reduced both the amount of winter deer forage and the canopy closure of conifers along the lake shore. Winter food provides energy to deer and conifer cover saves energy by intercepting snow and allowing deer to travel more easily. On Lake Muskoka, the presence of a conifer fringe would allow deer to conserve energy. When food is in short supply, deer alter their behaviour to conserve energy by reducing activity and seeking places were wind and temperature are moderated (Robinson 1960; Ozoga 1968; Moen 1976). These behavioral changes can reduce energy needs by up to about 30%. Although abundant accessible food supplies reduce the need for conifer cover, food supplies in this study were very low even on undeveloped shoreline. In the conifer forests of deer yards located elsewhere in central Ontario, we have measured 1-5 kg/ha of deciduous deer food (D. R. Voigt and J. D. Broadfoot, unpublished data). In this study, deciduous browse on undeveloped coniferous shoreline was less than 0.3 kg/ha. However, shoreline conifer habitat had large amounts of conifer food (> 20 kg/ha) suggesting that the shoreline habitat is especially important. After development of Lake Muskoka shoreline, deer food supplies were even lower near the edge of 60-100 m lots and near cottages. The larger openings created around cottages increased sunlight levels in the understorey. However, despite the increase in the size and number of gaps created in the shoreline fringe by development, there was no overall increase in the availability of winter deer food since cottage owners usually removed understorey brush or planted grass and flower beds in the open areas. This effectively removed most winter deer food. Average forage biomass on undeveloped shoreline was 4X greater than on cottage lots. We also noticed that cottage owners who removed fewer trees to avoid creating a manicured appearance to their properties tended to also remove less understorey and therefore provided higher levels of browse for deer.

Winter food supplies along the Lake Muskoka shoreline were low even before cottage development. Munro (1972, Ontario Ministry of Natural Resources, Parry Sound District, unpublished report) reported similar results from a winter deer food study on nearby Walker's Point, Lake Muskoka in 1970. Thus, the retention of conifer is more important in this situation than in areas where there is abundant browse. Since deer can move readily along windswept ice-covered shoreline in winter, gaps in the conifer fringe will not totally prevent deer movements along the shoreline. However, cottage development did reduce food supplies and remove conifers thus reducing winter carrying capacity for deer. Based on forage alone, undeveloped conifer sites could support 12 deer/km^2 (estimates based on Deer Camp Computer Simulation Model, Moen et al. 1986). Shoreline habitat near cottages could only support about 2 deer/km^2. Therefore, we conclude that an increased number of cottages or high intensity development reduced the winter carrying capacity of the Lake Muskoka shoreline for deer.

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General Features of Brook Trout, *Salvelinus fontinalis,* Spawning Sites in Lakes in Algonquin Provincial Park, Ontario

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Quinn, Norman W. S. 1995. General features of Brook Trout, *Salvelinus fontinalis*, spawning sites in lakes in Algonquin Provinical Park, Ontario. Canadian Field-Naturalist 109(2): 205–209.

Features of habitat and water chemistry at 17 Brook Trout spawning sites in lakes in Algonquin Park Ontario are described. The general appearance of the redds supported the hypothesis that upwelling groundwater is in short supply in the lakes. Proximity to surficial inflow shows potential as a predictive tool for locating sites. Total alkalinity of intergravel water indicated that redds are buffered but that eggs may sit in a mix of lake water and groundwater. Spawning activity persisted after logging had occurred adjacent to 10 sites but levels were unknown relative to pre-logging. The potential impacts of forestry on these habitats should be examined.

Key Words: Brook Trout, *Salvelinus fontinalis*, habitat, spawning, water chemistry, forestry, redds.

The stream spawning habitat of Brook Trout, *Salvelinus fontinalis*, is well described (e.g., Smith 1941) but site selection and general habitat features of sites in lakes are not as well documented. Fraser (1985) gave the definitive description of a lake spawning site in Algonquin Park, Ontario, and also that of what he considered an "atypical" site (Fraser 1982). Carline (1980) described development of artificial sites adjacent to three natural lake sites in Wisconsin and recently Curry (1993) studied the hydrology of three sites in lakes in Ontario. There is not, however, a summary description of typical habitat features from a representative number of sites.

Algonquin Park is an ideal place to do such work. The Park contains approximately 250 lakes with self-sustaining Brook Trout populations. Many of the lakes are, for all practical purposes, unexploited and habitat and fish communities are in nearly pristine condition. During fall of 1994, observations of habitat and measurements of water chemistry were made at 17 lake spawning sites identified from 1988-1994. The purpose was to provide a summary description of habitat and identify distinct or indicative features common to the sites.

Methods

The nearshore habitat of 41 lakes known to have self sustaining Brook Trout was searched from canoes in late October to mid November (during or after spawning had occured on known sites) for spawning activity or redds from 1988-1994. On several of the larger lakes mature fish (>30 cm) were fitted with internal sonic transmitters (Sonotronics Inc., Tuscon, Arizona) and tracked throughout fall to facilitate the searching. Brook Trout are philopatric to spawning sites (Webster and Eriksdottir 1976) and most sites were visited and confirmed at least twice during the years of search. Three sites were identified prior to 1988 by staff of the Algonquin Fisheries Assessment Unit.

In fall of 1994, once spawning had started, we visited every site and measured: the number of redds, depth and distance to shore of the shallowest and deepest redd, and distance to the nearest inflow (any clearly visible surface flow), outflow, and emergent vegetation. Aspect (compass heading at 90° from shoreline) was measured and slope of the adjacent terrain to 30 m and the horizon (as far as visibility permitted) was measured with a clinometer. A visual estimate of the total area cleared for the redds was also made. Tree and shurb species along shore adjacent to the redds were noted and the adjacent forest stand was described in terms of its major tree species, state of maturity, and whether recently logged or not (later verified from forestry records). The substrate type in the vicinity of the redds was also noted.

Brook Trout are generally believed to spawn in lakes over sites of upwelling groundwater which may differ in its chemistry from ambient lake water (Beggs and Gunn 1986). To examine this differential, one lake water sample and intergravel samples from the centre of three redds (if present) were taken at each site. If more than three redds were present the sampled redds were selected randomly by numbering the accessible redds and selecting from a random numbers table. The intergravel samples were taken by forcing a tygon plastic sampling tube inside a perforated steel probe to a depth of 12 cm, approximately the depth where Snucins et al. (1992) found lentic brook trout egg pockets. Samples were analyzed within 18 hours for pH and total inflection point (TIP) alkalinity. Lake and three intergravel measures of water temperature and oxygen were also taken using a thermistor probe (YSI Instruments, Yellow Springs, Ohio) shielded and inserted for

intergravel measures in the same manner. Redds deeper than about 1.5 m often could not be penetrated with the probe and for this reason no samples at all were collected from some sites.

Substrate samples were taken from redds at each spawning site using an Eckmann dredge. However, difficulty with dredge placement and loss of finer material, particularly at deeper redds, made quantitative substrate analysis impossible.

Results and Discussion

Fourteen spawning sites were found on only 12 of 41 lakes searched (sites on an additional three lakes were, as noted, already known). This inefficacy of searching was both frustrating and puzzling; all lakes were known to have self-sustaining Brook Trout and most have excellent water clarity and were searched thoroughly during the peak spawning period. Lentic Brook Trout have been reported to spawn in shallow water (e.g. Fraser 1985) but three of our sites (see below) were > 2.5 m deep. One (Animoosh Lake) was not visible from the surface and was located by diving on a site frequented by a telemetered fish. It is possible that sites were often deeper than we anticipated and due to this and observer fatigue they were overlooked, but the inefficacy of search effort remains an enigma. The use of sonic telemetry did not greatly improve success of searching; 21 fish were telemetered on 15 lakes and these "led" us to four spawning sites. Three of the telemetered fish, however, died within a few days after release. Twelve of 15 lakes had only one spawning site and the remaining three only two, supporting Fraser (1985) in his belief that suitable sites of upwelling water are not common on lakes.

The number of redds or, more accurately, clearings, at each site ranged from 1–28 but averaged only 6.7 and sites at several lakes had only 1–3 (Table 1). The individual cleared areas were often large and irregular, clearly the work of more than one female, and it was impossible to tell how many redds or egg pockets each clearing represented. These observations support Carline (1980) and Fraser (1985) who believed that restricted availability of upwelling water prevents females selecting individual sites for nesting and they superimpose their eggs on previously deposited eggs with subsequent high egg mortality (Fraser 1985). Indeed, the entire Brook Trout production of some sizable lakes (Little Dickson, Little Crooked, Westward) apparently comes from less than three, and sometimes only one, small cleared areas. Only two sites (Welcome, with 28 redds, and Charles) appeared as clusters of discrete, circular nests, each presumably the work of individual fish free to behave territorially.

Redds were generally close to shore in less than 1.5 m of water (Table 1) although one site (Amimoosh Lake) was 120 m from shore and in approximately 3.6 m of water. With the exception of distance to inflow (see below), there was nothing distinctive or clearly common to the sites and thus predictive for other sites. Slope, for example, ranged widely from virtually flat to steep (>15°) and aspect was also inconsistent (Table 1). Forest cover at shore was not notably distinctive, consisting of a mix of conifers typical of the riparian cover of the Park, and adjacent forest stands ranged from pure mature conifer to upland hardwoods and a grassy opening.

One feature, however, proximity to inflow, was potentially diagnostic. Eleven of 17 sites were less than 100 m from an inflow and 14 of 17 less than 200 m (Table 1)[1]. The affiliation of spawning sites with inflows was not simply incidental; lake inventory maps show a clear association (Figure 1). The observation is perhaps not surprizing since waterflow, both surficial and subterranean, must, intuitively, be similarly directed by local topography. Although the association was not absolute (and lakes were selected for Figure 1 to best illustrate it) the apparent relationship could be of real value to biologists assessing forestry or development plans on lakes for which spawning sites are unknown.

The uppermost layer of substrate around the redds was a fine, dark, organic detritus overlying gravel in 10 of 17 cases. The contrast between this dark material and the light cleared gravel areas made location of the sites, in most cases, strikingly obvious. Conversely, the detritus cover, which is widespread and effectively a "blanket" along the inshore of many Park lakes, would make location of possible spawning sites in summer impossible. The material recovers the clearings in most cases in late spring and completely obscures the promising gravel substrates below. The remaining sites had almost pure sand (three cases) sand and gravel (three cases) and gravel scattered amidst rock rubble in one case.

Intergravel alkalinity within redds was, as expected, higher that that of lake water ($\bar{x}$ redds = 10.19 mg/l lakewater = 6.10 mg/l, Table 2); and alkalinity of redds was higher at every site. Intergravel and lakewater pH were essentially the same ($\bar{x}$ 6.15 and 6.10 respectively, Table 2).

The higher intergravel alkalinity is consistent with the hypothesis (Beggs and Gunn 1980) that groundwater provides a relatively buffered refugium for developing brook trout eggs. It is significant, however, that the levels of alkalinity reported here are markedly lower than those obtained from the Westward, Little Crooked and Redrock lake sites via piezometers set well beneath Brook Trout redds and presumably sampling pure groundwater (F. J. Hicks,

[1]The site at Dickson Lake, described by Fraser (1985) is also directly adjacent to an inflow.

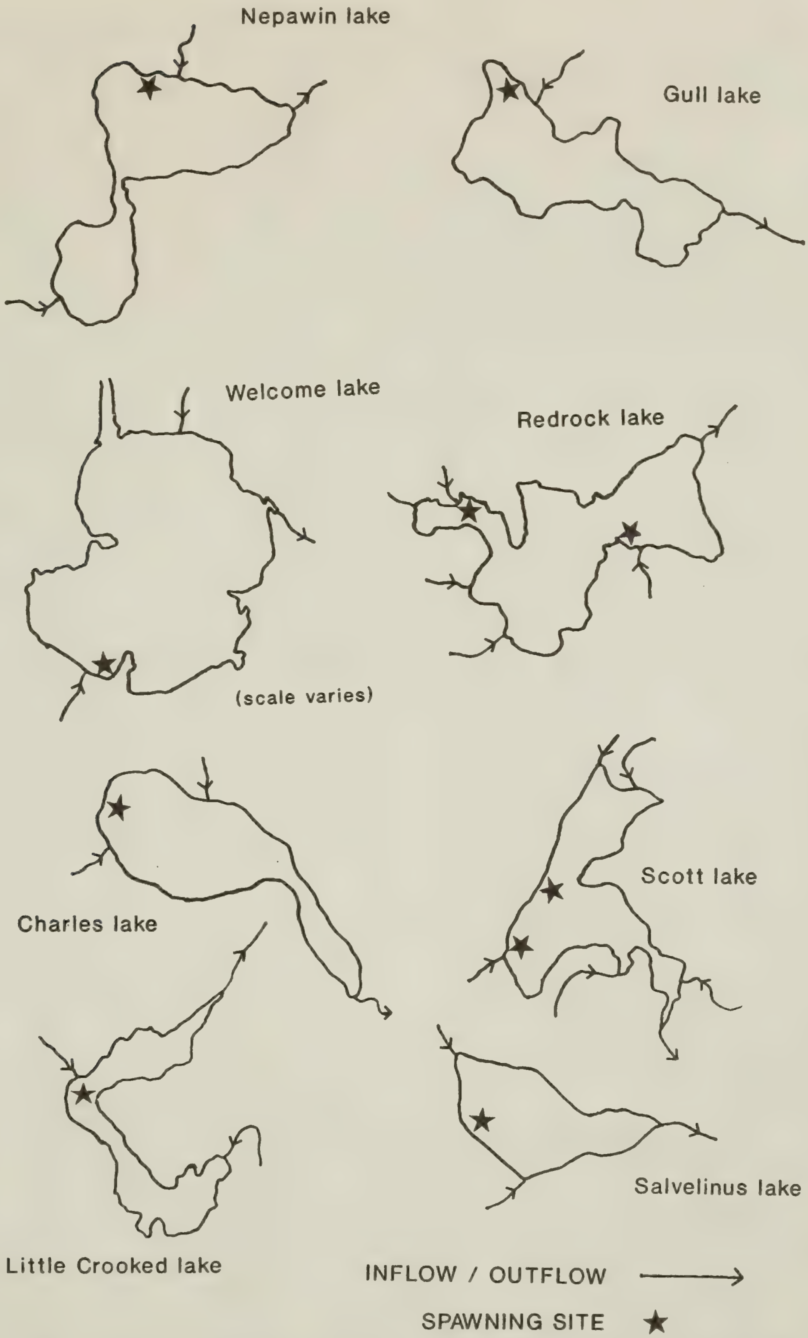

FIGURE 1. Location of lentic Brook Trout spawning sites in eight lakes in Algonquin Park Ontario, showing proximity to inflows.

Ontario Ministry of Natural Resources unpublished). Our data from within redds therefore suggest that eggs at about 12 cm depth are bathed in a mix of groundwater and ambient.

Overall intergravel oxygen was lower than ambient ($\bar{x}$ (mg/ℓ) redds = 7.76, lakewater = 10.05, Table 2); lakewater higher at all but one site. Fraser (1985) reported comparable intergravel oxygen in Dickson

Table 1. Habitat features of lentic (lake) Brook Trout spawning sites in Algonquin Park, Ontario.

Lake	Lake Area(ha)	Redds: Number	Depth (m): Shallowest	Depth (m): Deepest	Approximate Area (m^2)	Distance from shore(m): Shallowest	Distance from shore(m): Deepest	Aspect	Slope to: 30 m	Slope to: Horizon	Distance [2](m) to: Horizon	Distance [2](m) to: Inflow	Distance [2](m) to: Emergent Vegetation
Gull	25.0	4	1.4	2.2	9	3.3	4.0	185°	5°	10°	300	134	None
Animoosh	58.3	6	3.6	3.6	[1]	120	120	125°	5°	4°	∞	351	None
Casey	16.2	5	1.7	1.2	25	5.5	7.0	34°	5°	17°	197	55	None
Charles	12.4	9	0.5	0.5	25	4.5	5.9	86°	8°	8°	∞	99	99
Little Canoe	17.7	3	0.4	0.5	1	1.5	2.5	109°	12°	18°	61	40	0
Guskewau	11.9	5	1.2	1.4	12.5	4.3	5.5	355°	11°	5°	64	252	73
Little Dickson	118	1	0.3	–	3	3.1		290°	0°	0°	∞	23	None
Little Crooked	92.1	3	0.2	0.4	34	1.5	6.3	165°	0°	0°	∞	110	None
Nepawin	34.9	2	0.7	1.1	3.5	1.37	1.7	164°	8°	18°	∞	58	42
Redrock[3]	293	12	0.4	0.6	56	0.9	0.3	204°	14°	19°	500	66	None
Salvelinus	6.8	1	2.6	–	2.5	15.1	–	60°	9°	9°	150	183	None
Welcome	260	28	0.5	0.8	75	2.3	12.8	315°	6°	6°	∞	76	None
Westward	62.8	1	3.5	a	1	3.1	a	82°	12°	19°	500 m	23	None
Scott	27.6												
Site 1		12	1.3	1.7	20	6.1	19.8	90°	12°	18°	122 m	23	0
Site 2		6	1.7	2.5	10	6.1	9.2	110°	12°	12°	150 m	387	None
Stringer	33.5												
Site 1		14	0.9	1.9	95	6.1	16.8	335°	0°	0°	∞	38	None
Site 2		2	1.2	1.8	12	1.83	3.1	180°	12°	12°	∞	61	None

[1]Redds not visible from surface - area not measured.
[2]∞ here means the horizon was distant, too far to measure on the ground.
[3]Redrock lake has two spawning sites, only one was visited before ice up.

TABLE 2. Mean water chemistry values within Brook Trout redds[1] and of ambient lake water, Algonquin Park, Ontario.

Source	Alkalinity (mg/l)	pH	Dissolved Oxygen (mg/l)	Temperature (°C)
Redds	10.19 (SE=1.67, N=28,11)[2]	6.15 (SE=0.07, N=28,11)	7.76 (SE=0.28, N=31,11)	3.75 (SE=0.33, N=31,11)
Ambient (lake)	6.10 (SE=0.12)	6.10 (SE=0.12)	10.05 (SE=0.48)	3.94 (SE=0.62)

[1]Samples taken from approximately 12 cm deep into centre of redds.
[2]N in all cases is number of redds followed by number of lakes, only one lake water sample was taken at each site.

Lake and that oxygen was stable in redds through one winter but declined through another. Our lowest intergravel oxygen reading (4.70 mg/ℓ, Little Dickson Lake, one redd) was marginal but sufficient for development of Brook Trout eggs (Garside 1966) if sustained. Intergravel water temperature was essentially identical to ambient ($\bar{x}$ °C intergravel = 3.75, lakewater = 3.94, Table 2). This similarity was coincidental to the fall cooling of ambient water. Fraser (1985) reported slightly lower intergravel temperatures in midwinter in Dickson Lake and that the upwelling water (warmer than ambient at that point) prevents freezing in the gravel near shore.

Logging of adjacent forest stands had occurred at 10 of 17 sites since 1969 (six from 1969-1987 and four from 1988-1990). The forest harvest system was selection cut of hardwood in seven cases and shelter-wood cut of softwood in the remaining three. In all cases the entire watershed to at least 500 m from shore was harvested (although a 30 m no cut reserve from shore is maintained). The post-logging use of these sites by Brook Trout is significant. Although there has been extensive research on the effects of logging on surficial water quality (Chamberlin et al. 1991) effects on fish habitats associated with subterranean water are, to my knowledge, unknown. Biologists in the Park have wondered for some time whether logging in the vicinity of these ecologically sensitive sites could, via effects on the water table, (Chamberlin et al. 1991, page 187) modify delivery of groundwater and influence use of the sites by Brook Trout. Although we have no pre-logging records of spawning our observations demonstrate at least that any change to waterflow that may have occurred was not sufficient to cause abandonment of these sites. This question, and particularly effects under more aggressive systems of logging, is a most worthy area for further investigation.

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Summer Activity of Northern Pocket Gophers, *Thomomys talpoides*, in a Simulated Natural Environment

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The summer temporal and spatial activity patterns of six Northern Pocket Gophers (*Thomomys talpoides*) individually introduced into a 120- × 240- × 10-cm observation chamber replicating their natural environment were studied for 48 continuous h during summer 1993. The behavior of the gophers varied greatly from one animal to another. On average, gophers spent 53% of their time sleeping. They spent more time excavating (763 min or 56% of 1362 min of activity) than any other active behavior. Burrow systems had a zigzagging or looping pattern, an average length of 408 ($\pm$ 28) cm, and at least one nest chamber, usually > 90 cm below surface. Pocket gopher activity occurred throughout the 24-h day and there was no difference ($P > 0.05$) between the sum of activity periods recorded during different times of the day. Although most of their activity occurred below ground, gophers spent an average of 2.7 h on surface for food-related activities.

Key Words: Northern Pocket Gopher, *Thomomys talpoides*, behavior, burrow systems, simulated natural environments, daily activity.

Obtaining behavioral information on the Northern Pocket Gopher (*Thomomys talpoides*) is difficult because its activities are concentrated in a burrow system. Live-trapping is not a useful technique for determining the relationship between gopher activities and the burrow system's layout because it does not allow continuous monitoring (Cameron et al. 1988). Daily activity patterns of free-ranging gophers can be determined with radiotelemetry and radionucleotides (Andersen and MacMahon 1981; Gettinger 1984), but specific activities may not be differentiated from each other.

Because of the limitations of techniques used to study pocket gopher behavior, much is yet to be learned of the Northern Pocket Gopher summer activity rhythm (Chase et al. 1982). It is believed that most species of pocket gophers have a similar 24-h cycle (Vaughan and Hansen 1961). Light or darkness apparently has no effect on activity and there are no clear activity peaks (Vaughan and Hansen 1961; Andersen and McMahon 1981; Cameron et al. 1988). In contrast, Tryon (1947) suggested that Northern Pocket Gophers had two major peaks of activity, one in late afternoon and one immediately after dawn. Wilks (1963) reported that the Plains Pocket Gopher (*Geomys bursarius*) was more active in the morning in summer. Gettinger (1984) reported that the Valley Pocket Gopher (*Thomomys bottae)* was more active between 16:00 and 22:00 h.

Studies of the relationship between gophers' activities and their burrow's structure have also led to diverging conclusions. According to Tryon (1947), the bulk of the Northern Pocket Gopher's food is gathered by extending tunnels under the roots of the vegetation. It was also suggested that the Plains Pocket Gopher (Andersen 1987, 1988) and the Valley Pocket Gopher (Bandoli 1981) developed their burrow system to access food. However, Cameron et al. (1988) concluded that the architecture of the Attwater's Pocket Gopher (*Geomys attwateri*) burrow system was not related to resource availability.

The objective of this study was to gather more information on the Northern Pocket Gopher's summer behavior by studying the daily activities and characteristics of burrow systems of animals individually introduced into a simulated natural environment.

Materials and methods

The study was carried out from 28 June to 11 August 1993 in Vegreville, Alberta. The temporal and spatial activities of six gophers individually introduced in a 120- × 240- × 10-cm indoor plexiglass chamber (Figure 1) were monitored for 48 continuous hours. The chamber was filled with topsoil and kept continuously in the dark. The top of the chamber was 36 cm wide and was enclosed by a 100-cm high wire mesh covered with cardboard. Vegetation, mainly alfalfa and grasses, was transplanted with a $\geq$ 15 cm long root system and subjected to a normal day-night cycle. A floodlight, which automatically turned on and off at 07:35 and 22:20, respectively, illuminated the top of the chamber but did not shine on the chamber's underground portion.

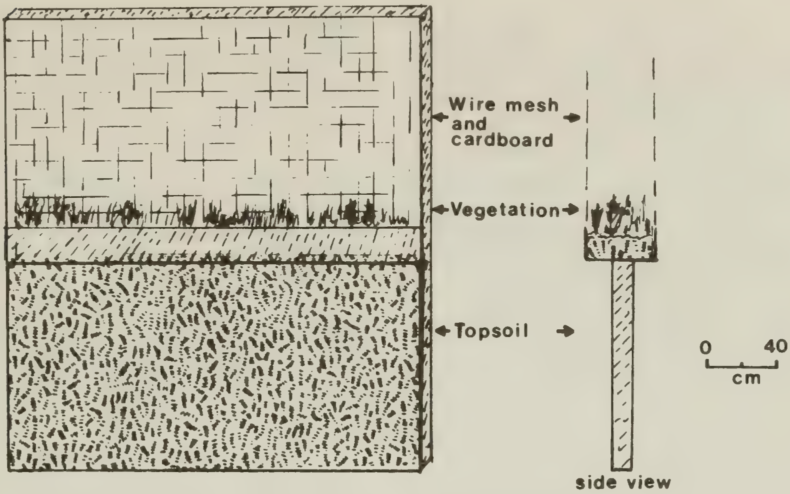

FIGURE 1. Diagram of the observation chamber.

The underground behavior of gophers was recorded with two remote control Panasonic WV1854 videocameras set on each side of the chamber. The cameras were equipped with a Comiscar 15-180 mm f/1.9 1500 lens and a high efficiency 500 W infrared light illuminator (Avicom Industrial Communications, Edmonton, Alberta). A miniature infrared Sanyo 9212 videocamera (Norsat, Edmonton, Alberta) was hung over the chamber to record the activities of gophers above ground. However, this was not a remote control camera and gophers' movements could not be continuously followed. All cameras were connected to AG-6010 Panasonic videorecorders.

Five juveniles (numbers 1 to 4: males; number 6: sex unknown) and one adult (number 5: sex unknown) were live-trapped in a nearby alfalfa field and kept in captivity at least one day before being released on the top of the observation chamber. Five of them were released between 09:00 and 10:20; one gopher was introduced in mid-afternoon. The following behaviors were recorded: exploration above ground, excavation underground (including tunnel blocking), feeding, food gathering, food transport, grooming, and sleeping (including naps). With the exception of the exploration and surface excavation of animals at release time, all gophers' activities above ground were associated with feeding or food gathering. These behaviors were therefore pooled together when determining the time spent above ground by gophers.

Measuring tapes placed along the base and on one side of the observation chamber were used to estimate the dimensions of the tunnel system. We also used an average gopher body length (without the tail) of 15 cm (Burt and Grossenheider 1976) to assess the length of a newly dug tunnel and determine the excavation rate (cm/min). At the end of a 48-h observation period, the resident gopher was trapped out. The gopher's mounds were levelled and the first 30 cm of topsoil turned over to remove all signs of surface burrowing activity. The deep portion of the gopher's tunnel system was left untouched, as is the case in the real world where the upper structure of an abandoned burrow system deteriorates over time or is destroyed by farm machinery. New vegetation was transplanted and a new animal was introduced one week later.

A Kruskal-Wallis one-way analysis of variance by ranks (Siegel 1956) was used to compare the sum of all active behaviors (therefore excluding sleeping/resting periods) of gophers during the first, second, third and fourth 12-h periods. If the test indicated that the time period had an effect on the amount of activity, mean durations of active behaviors for each time period were compared to each other with a t-test (Dixon and Massey 1969). The second and third 12-h periods of each 48-h study were also subdivided into 6-h time periods: 21:00 to 03:00 and 03:00 to 09:00 periods that were dominated by darkness, and 09:00 to 15:00 and 15:00 to 21:00 periods with the above ground floodlight turned on. The sum of gophers' active behaviors during these periods were also compared to each other with a Kruskal-Wallis test. Mean excavation rates in undisturbed and disturbed (the first 30 cm of topsoil turned over after the removal of a gopher) soils, and mean durations of gophers' exits during food harvests, were compared to each other with a t-test (Dixon and Massey 1969).

Animal husbandry and research procedures were endorsed by the Alberta Research Council's Animal Care Committee and were in accordance with the guidelines of the Canadian Council on Animal Care (1984).

Results

Behaviors

The behavior of gophers varied greatly from one animal to another. On average, gophers were active 1362 (SE = 135) min of the total 2880 min of observations (Table 1). Gophers spent more time sleeping/resting (52.7%) than being active (47.3%) (χ^2 = 8.540, df = 1, P = 0.005). Gophers usually slept in nests that were also used as food caches. It was sometimes difficult to identify brief activity changes when the chamber's plexiglass was dusty. However, it appeared that three gophers were leaving their nest in order to relieve themselves. We observed gopher number 1 leaving its nest and going to the end of a lower tunnel to apparently defecate and groom itself. The animal often blocked this area with dirt. The same behavior was repeatedly observed at the end of the same tunnel with gophers numbers 3 and 4.

On average, gophers spent more time excavating (763 min or 56% of 1362 min of activity) than any other active behavior. The mean excavation rate of four gophers in undisturbed soil, based on eight records, was 3.8 (± 0.2) cm/min. However, after removing a gopher and turning over the surface topsoil, four observations on three newly introduced gophers showed that the animals could dig through loose soil at a significantly (t = 9.697, P = 0.005) greater average speed (9.0 ± 0.6 cm/min).

The animals spent, on average, 405 min (14% of the total 2880 min of observation, or 30% of the 1362 min of activity) feeding. Most of the feeding occurred below ground but consisted mostly of plants gathered on surface (Table 1). The animals still spent an average of 62 min feeding above ground. Considering that the mean duration of food harvests on surface was 102 (± 18) min, gophers allocated a total of 164 min (2.7 h or 5.7% of the 48-h period) on surface for food-related activities.

On average, gophers had 5 (± 0.6) food harvests during the 48-h period. The harvests lasted, on average, 22 (± 3) min and were comprised of a series of exits with a mean duration of 1.9 (± 0.4) min during the day and 2.4 (± 0.4) min during the night. There was no significant difference between the mean duration of the day and night exits (t = 0.850, P > 0.05). Gophers harvested their food by the surface entrance of their tunnel (which corresponded to an earth plug) or walked above ground to clip and stuff plant stems in their cheek pouches. Recordings with the miniature infrared videocamera showed gophers travelling > 60 cm away from the earth plug to cut plants.

Temporal Distribution of Activities

The sums of activities/12-h period were significantly different from each other (H = 28.5, df = 3, P = 0.001). Gophers were significantly more active during their first 12 h of residence ($\bar{x}$ ± SE = 486 ± 13 min) than during the second (275 ± 69 min; t = 3.028, $P < 0.05$), third (330 ± 53 min; t = 2.869, $P < 0.05$) and fourth (290 ± 64 min; t = 3.000, $P < 0.05$) 12-h periods.

To test for a relationship between total activity and time of the day, we used a 24-h period that excluded the first and last 12 h of residence. Pocket gopher activity occurred throughout the 24-h day, and there was no difference between the sums of activities recorded during different periods of the day (H = 0.17, df = 3, P = 0.99). The mean total activity/6-h-period ranged from 144 to 165 min. There was no relationship (P > 0.05) between specific activity types (i.e., digging, sleeping,...) and time of day.

Burrow Systems

The length and shape of burrow systems were greatly influenced by the burrowing activities of gopher numbers 1 and 5 (Figure 2). Burrow systems usually consisted of a main tunnel with short lateral ones, and a single exit to the surface. Gopher number 1 completed a zigzagging burrow system 30 h after its release in the chamber. Gophers numbers 2 and 3 initiated their own burrow system but after 10 and 4 h of excavation, respectively, they connected with gopher number 1's remaining burrow system, approximately 30 cm below ground (Figure 2). They immediately adopted the old burrow system. Gopher number 4 connected with and adopted the old burrow system 16 h after its release. However, 26 h later (42 h after its release), it changed it into first a C-shaped tunnel and, after, an incomplete circle (Figure 2). Adult gopher number 5's tunnel had a looping structure. A few side tunnels branched off from the main tunnel. Gopher number 6 initiated its own system but 2 h after its release in the chamber, it connected with gopher number 5's leftover tunnel

TABLE 1. Importance (number of minutes) of behavioral activities of Northern Pocket Gophers in a simulated natural environment.

Behavior	Number of minutes $\bar{x}$	%	SE
Sleeping	1511	52.5	132
Digging	763	26.5	98
Feeding underground	343	11.9	90
above ground	62	2.2	30
Food harvesting	102	3.5	18
Surface exploration at release time	27	0.9	9
Grooming	19	0.7	8
Underground transport of vegetation	53	1.8	17
Total	2880	100.0	–
Total active	1362	47.3	135
Total inactive	1518	52.7	135
Total on surface	190	6.6	44
Total underground	2690	93.4	44

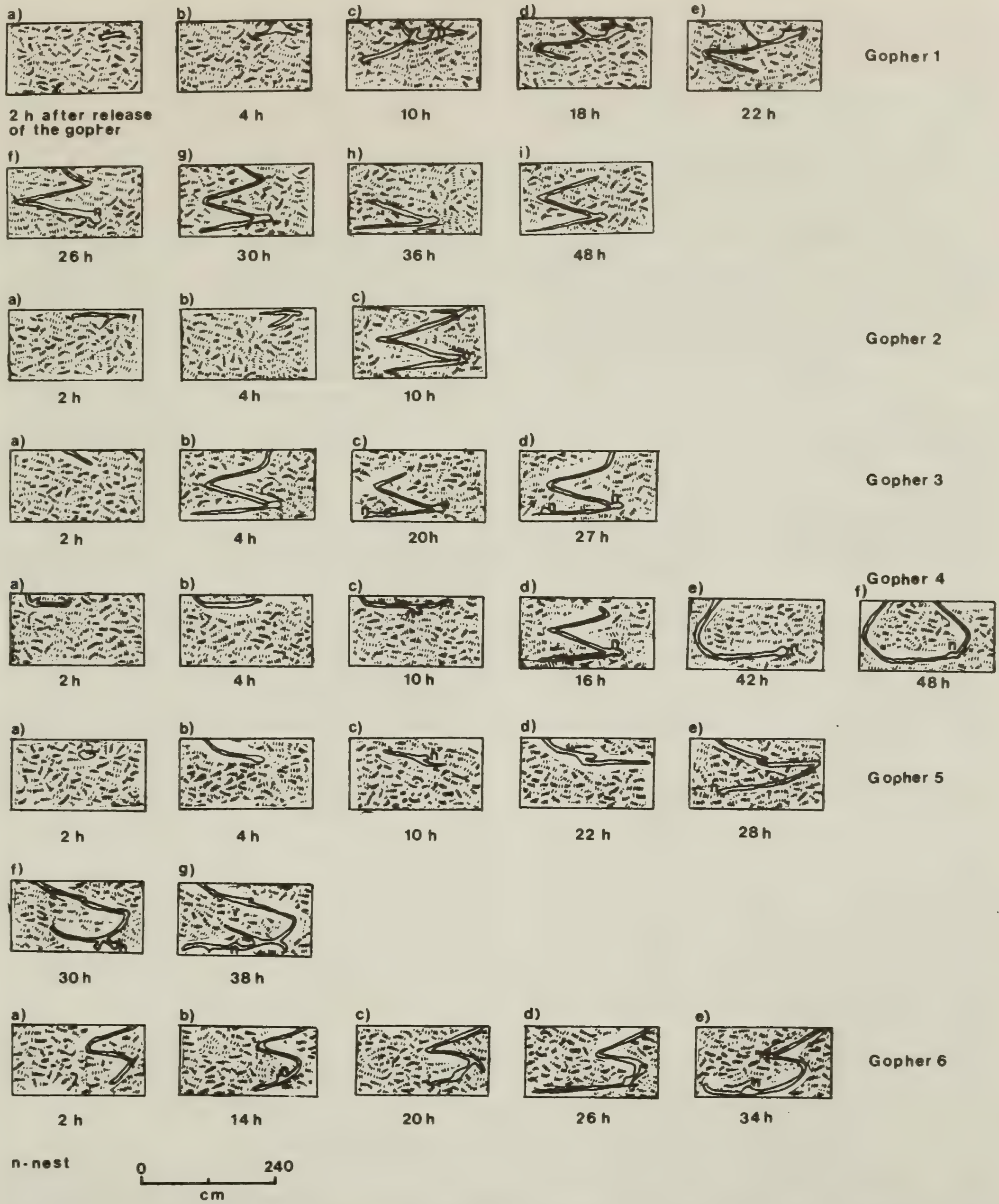

FIGURE 2. Temporal and spatial characteristics of six Northern Pocket Gophers' burrow systems in a simulated natural environment.

and immediately adopted it (Figure 2). The linear length of all the burrow systems ranged from 340 to 500 cm and averaged 408 (± 28) cm.

Gophers numbers 1 and 5 rested in nests dug 15 and 20 cm, below ground. However, after 24 and 28 h of excavation, respectively, both gophers had established deep tunnels and moved their nest lower. Gopher number 1 made its nest 90 cm below ground. Gopher number 5 established three nests located 90, 105 and 110 cm below ground. Gopher number 4 originally slept in its newly excavated tunnel 15 cm below surface and gopher number 2 rested in a nest 5 cm underground. However, both animals abandoned their resting places once they found gopher

number 1's remaining tunnel and adopted the old nest, 90 cm below surface. Gophers numbers 3 and 6 found the old tunnels soon after initiating their own burrow system and readily adopted the nests of the previous occupants. At the end of the 48-h study, all the animals were using nests that were $\geq$ 90 cm below surface. The majority of nests had only one access tunnel (Figure 2).

Except during their food harvests, gophers kept their burrow system plugged at the surface level. However, four out of six gophers also blocked upper tunnel sections so that the portion of the burrow system that was occupied by the animals was inaccessible at the surface level (Figure 2, gophers numbers 1 h and i, 3c, 4d and 5c).

Discussion

Fossorial mammals are neither nocturnal nor crepuscular and tend to be active during both day and night (Nevo 1979). Our study suggests that this is true for the Northern Pocket Gopher. Our conclusion contradicts studies (Tryon 1947; Wilks 1963; Gettinger 1984) suggesting that gophers had daily peaks of activity. Our findings are, however, in agreement with several studies (Howard and Childs 1959; Vaughan and Hansen 1961; Andersen and MacMahon 1981; Cameron et al. 1988) which suggested that daily activity of pocket gophers was random. Vaughan and Hansen (1961) suggested that gophers' fossorial mode of life resulted in the absence of a daily cycle. Instead, they appear to be governed primarily by their high metabolic demands.

Previous studies pointed out that gophers' activity corresponded to 50% of their time or less (Vaughan and Hansen 1961; Andersen and MacMahon 1981; Gettinger 1984). In this study, gophers spent slightly more than 50% of their time sleeping. Their main activity consisted of excavating and maintaining their burrow system. The gophers' mean excavation rate of 3.8 cm/min was greater than those reported by Richens (1966; 3 cm/min) and Gettinger (1984; $\leq$ 2 cm/min) and Andersen (1987; $\leq$ 2.8 cm/min). These various burrowing rates probably reflect differences in soil consistency (Chase et al. 1982). Our observation chamber was narrow and did not allow gophers to excavate long lateral tunnels reported by Turner et al. (1973). The zigzagging or looping pattern of the gophers' burrow system involved a tunnel reaching to a deep nest chamber as previously reported for the Northern Pocket Gopher (Tryon 1947), the Attwater's Pocket Gopher (*Geomys attwateri*) (Cameron et al. 1988) and the Southeastern Pocket Gopher (*G. pinetis*) (Brown and Hickman 1973). It is usually considered that gophers establish their nest 30 to 75 cm below the surface (Tryon 1947; Turner et al. 1973). In our study, the nests were usually located at greater depths ($\geq$ 90 cm).

Aldous (1951) reported that ordinarily gophers do very little travelling above ground. The greatest amount of plant removal above ground occurs near the surface opening of the runway. Also, the greater part of the gophers' food would come from burrowing just below the surface and collecting the bulk of the plant food encountered as digging progresses. Tryon (1947) and Andersen (1987, 1988) also suggested that gophers accessed their food by extending their burrow system. In this study, gophers did not gather their food by extending their tunnels along the top of the observation chamber and they did not limit their feeding activities to the burrow opening. Our finding that gophers spent nearly three out of 48 h on surface for food-related activities points out that the importance of above ground activities in the life history of pocket gophers may have been underestimated by previous studies using different investigative methods.

Tunberg et al. (1984) found that pocket gophers often investigated and took over abandoned burrow systems within seven days after the original occupant gopher was removed by trapping. Our study showed that when gophers encountered an old burrow system, they readily accepted it. They even abandoned their own nest in favor of old ones. Gophers numbers 3 and 4 also used gopher number 1's latrine to relieve themselves.

Because of the similarities between the burrow characteristics and the lack of summer activity rhythm of our captive animals and those of free-ranging animals (Turner et al. 1973; Chase et al. 1982; Cameron et al. 1988), we assume that the behavior of our captive Northern Pocket Gophers approximated that occurring under natural conditions. Our study, however, was dominated by juvenile males. Although there were similarities between their behavior and that of adult gopher number 5, more work should be carried out with adult animals. The behavior of female juveniles and adults introduced into a simulated natural environment should also be studied and compared to that of the juvenile males of this study in order to identify behaviors that may be related to age and sex classes.

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Straw-colored Capsules of Sand Dune Long-stalked Chickweed, *Stellaria longipes* subspecies *arenicola* (Caryophyllaceae), in the Sand Dunes of Lake Athabasca, Saskatchewan

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Ramamoorthy, Jeyanthi, and C. C. Chinnappa. 1995. Straw-colored capsules of Sand Dune Long-stalked Chickweed, *Stellaria longipes* subspecies *arenicola* (Caryophyllaceae), in the sand dunes of Lake Athabaska, Saskatchewan. Canadian Field Naturalist 109(2): 216–219.

Long-stalked Chickweed, *Stellaria longipes* is a circumpolar species with a wide range of morphological variation and phenotypic plasticity. Most populations of *S. longipes* have black or dark brown capsules. However, the populations in the sand dune system of Lake Athabasca, *S. longipes* subsp. *arenicola*, posses straw-colored capsules. The present study was carried out to investigate the anthocyanidin pigment patterns of the black, brown, and straw-colored capsules. Differences in pigment patterns were evident for the three capsule colors. It is hypothesized that plants with straw-colored capsules are being selected in the sand dune habitat.

Key Words: Sand Dune Long-stalked Chickweed, *Stellaria longipes* subsp. *arenicola,* anthocyanidins, capsule color, Lake Athabasca, Saskatchewan.

Anthocyanidins are a class of flavonoid compounds which contribute to the diversity of color in plants (Van Tunen and Mol 1990). Because the compounds are easily visible and mutations affecting their accumulation are not lethal (Gantet et al. 1993), they have been extensively characterized at both the biochemical and physiological levels (Harborne 1988). Modifications to the flavonoid skeleton such as hydroxylation, methoxylation, glycosylation and acylation, bring about different colors. Combinations of anthocyanidins, presence of co-pigments and pH differences influence the extent and quality of colors (Harborne 1988). The simplest pigment, cyanidin-3-glucoside is also the most common anthocyanidin in fruits (Harborne 1967). In many instances, color is due to the amount of each pigment rather than the nature/type of anthocyanidin (Harborne 1967). Anthocyanidins have also been shown to be environmentally and developmentally regulated (Manicelli 1990; Gantet et al. 1993).

The Long-stalked Chickweed, *Stellaria longipes* is a widely distributed species in North America, exhibiting extensive morphological variation and phenotypic plasticity (Chinnappa and Morton 1984). Most populations of *Stellaria longipes* have black or dark brown capsules. However, an exception is the populations in the sand dune system of the Lake Athabasca region. In this unique habitat, the capsules are straw-colored (Figure 1). These populations (*S. longipes* subsp. *arenicola*) are endemic to the sand dunes and have been suggested to have evolved recently in that habitat (Raup and Argus 1982; Chinnappa and Morton 1976, 1991; Macdonald et al. 1987). The present study was initiated to evaluate the nature of the pigment patterns of black, brown and straw-colored (yellow) capsules of *S. longipes*.

Materials and Methods

Capsules from fourteen populations of *Stellaria longipes* grown in the experimental garden at the University of Calgary (Table 1) were examined for anthocyanidin content. Anthocyanidins from capsule tissue (0.5 grams) were extracted by a standard procedure using 1% HCl in methanol (Markham 1982). Combined extracts from sequential extractions were collected and concentrated using a rotary flash evaporator. Since the capsule tissue was dry, the anthocyanidins were assumed to be present in a hydrolyzed state (without glycosyl residues) (Markham 1982). To confirm this, some of the anthocyanidin extracts were first hydrolyzed in 2N HCl (Harborne 1967), chromatographically analyzed and compared with unhydrolyzed sample extracts of the same population. No difference in spot Rf values, color or size of spots was apparent (unpublished data). This suggests that the anthocyanidins were only present in the aglycone or anthocyanidin configuration in the capsule tissue.

Methanol-HCl extracts were analyzed by thin layer chromatography following procedures outlined in Stahl (1969). Glass plates with a 250 μ cellulose layer were used for the chromatography (Terochem Laboratories Inc.). All the plates were run in closed glass tanks containing approximately 100 ml of the solvent system. Initial separation and characterization of the anthocyanidins were achieved using three consecutive solvent systems. These systems were n-butanol:acetic acid:water (4:1:5, top layer) (BAW

FIGURE 1. Capsules of *Stellaria longipes*. A. Straw-colored, B. Black-colored.

system), followed by acetone:HCl (5:1), and 1% HCl in water (Arditti and Dunn 1969). Isolated spots were eluted from the cellulose with 1% HCl in methanol and analyzed using the BAW system described previously, or n-butanol:2N HCl (1:1). Other solvents described by Harborne (1967) were employed but did not produce satisfactory separation of the pigments. These solvents included t-Butanol:acetic acid:water (3:1:1), 15% acetic acid, formic acid:water:HCl (5:3:2), and 1% HCl in water. Anthocyanidins were characterized by the Rf values of both the isolated spots and the spots from the initial separation using three systems, spectral analysis of the isolated compounds, and the color of the spots in UV light (Arditti and Dunn 1969).

Results and Discussion

Pigment contents of the fourteen populations are summarized in Table 2. Cyanidin, malvidin and luteolinidin were the only anthocyanidins evident in capsules of *Stellaria longipes*. Black capsules contained all three anthocyanidins with cyanidin in the largest proportion. Brown capsules contained more malvidin than cyanidin yet had the same proportion

TABLE 1. List of populations used in the present study, collection sites and their ploidy.

Accession Number	Collection Site	Ploidy
4716	Waterton National Park, Alberta	$2n = 52$
223	Nose Hill, Alberta	" = "
569	Longview, Alberta	" = "
530	Exshaw, Alberta	" = "
4766	Yellowstone National Park, Wyoming	" = "
817	Hawk Hills, Northwest Territories	" = "
133	Lake Athabasca Sand Dunes, Saskatchewan	" = "
113	" " " " "	" = "
214	" " " " "	" = "
3867	Cypress Hills, Alberta	$2n = 78$
798	Little Buffalo Falls, Northwest Territories	" = "
7332	Rocky Mountain National Park, Colorado	$2n = 104$
7294	Beartooth Pass, Wyoming	" = "
879	Quirpon, Newfoundland	" = "

TABLE 2. Pigment composition of seed capsules from fourteen populations of *Stellaria longipes*.

Capsule Color	Accession Number	Ploidy (2n)	Anthocyanidins Cyanidin	Malvidin	Luteolinidin
Black	4716	52	+++	++	+
	233	52	++	+	+
	569	52	++	+	+
	817	52	++	+	+
	530	52	++	++	+
	798	78	++	+	+
	7294	104	+++	+	+
	7332	104	++	+	+
Brown	4766	52	−−	++	+
	3867	78	++	+++	+
	879	104	++	+++	+
	214x569 F1	52	−−	++	+
Straw	133	52	_	−−	++
	136	52	+	−−	++
	214	52	+	−−	++

+ = present pigment complement
++ = present in larger proportions in pigment complement

of luteolindin. Straw-colored capsules did not contain any malvidin. All capsules contained at least some quantity of luteolinidin.

Black capsules of the different ploidy levels all contained the three anthocyanidin groups. The brown capsules had different proportions of the three anthocyanidins. All capsules examined had a small proportion of luteolinidin but malvidin and cyanidin did not appear in all populations. The luteolinidin pigment could be an intermediate or side product in the biosynthesis of malvidin and cyanidin (Harborne 1977). Cyanidin is a pentahydroxy derivative of the basic flavonoid structure, whereas luteolinidin is a tetrahydroxy derivative. Luteolinidin has been assumed to be derived from cyanidin during synthesis (Harborne 1977). However, this would not explain why luteolinidin is found in accession numbers 133, 136 and 214 in a larger proportion than cyanidin (Table 2). Since cyanidin is the luteolinidin precursor, it should be present in slightly larger pools than luteolinidin. *Stellaria* plants may be selecting for increased luteolinidin conversion. This could be occurring in plants with straw-colored capsules. Malvidin is synthesized by a different pathway that has been proposed for cyanidin and luteolinidin synthesis (Harborne 1977). The lack of any correlation between malvidin and cyanidin concentrations supports the idea of a separate pathway. Moreover, the malvidin structure of a methyl ether group in the 3′ and 5′ positions on the basic flavonoid structure indicates an alternate malvidin synthesis route (Harborne 1977).

F_1 plants obtained from a cross between straw-capsuled plants (accession number 214) and black-capsuled plants (accession number 569) had brown capsules. However, the brown color was made up of malvidin and luteolinidin only. This pigment combination was also found in accession number 4766. Cyanidin could not be detected in the F_1 brown capsules; but they were seen in accessions 3867 and 879.

Most populations of *S. longipes* are outbreeders. From the analysis of 1000 specimens from North America, it was noted (Chinnappa 1973) that 77% had black capsules and 23% brown capsules. Chinnappa and Morton (1984) reported that the pigment expression of capsules are under polygenic control. The predominantly straw-colored plants in the sand dune system are of interest. In the sand dunes, there is bright sunlight and intense heat in summer and the black color capsules may have adaptive disadvantages. Hence, these plants might have developed not only straw color capsules but they also dehisce to release the seeds soon after maturation (personal observations). These genotypes (*S. longipes* subsp. *arenicola*) are presumably being selected and maintained by switching the breeding system from cross-pollination to self-pollination (Chinnappa and Morton 1984; 1991). Further studies on the ecophysiology and reproductive biology of the sand dune populations are in progress.

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Fourteenth Census of Seabird Populations in the Sanctuaries of the North Shore of the Gulf of St. Lawrence, 1993

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The fourteenth census of seabirds in the sanctuaries on the North Shore of the Gulf of St. Lawrence revealed major changes in the area's seabird community. Among the larids, a sharp decline was observed in the Herring Gull population, which may be related to the decreased availability of fish offal. Other larid numbers also decreased, including Black-legged Kittiwakes, Ring-billed Gulls, Common Terns, Arctic Terns and Caspian Terns. On the other hand, alcid populations — Common Murres, Razorbills and Atlantic Puffins — increased. It appears that the small prey fish (sand lance and capelin) that alcids feed on are still in plentiful supply, which may partly explain these increases. The continuation of vigorous enforcement programs in sanctuaries where numerous alcids breed also contributed to their increase.

Le quatorzième inventaire des refuges de la Côte-Nord du golfe Saint-Laurent a révélé des changements importants au sein de la communauté des oiseaux de mer. Chez les Laridés, le Goéland argenté a considérablement diminué et cette baisse pourrait être reliée à une réduction des déchets de poissons. D'autres espèces de Laridés ont également diminué soit la Mouette tridactyle, le Goéland à bec cerclé, les Sternes pierregarin et arctique et la Sterne caspienne. Par contre chez les Alcidés, la Marmette de Troïl, le Petit Pingouin et le Macareux moine ont augmenté. Il semble bien que les petits poissons (lançons et capelans) continuent d'être abondants et disponibles pour les Alcidés. Le maintien du gardiennage dans des refuges propices à la nidification des Alcidés pourrait expliquer en partie ces hausses.

Key Words: Seabirds, populations, sanctuaries, Gulf of St. Lawrence, Common Eider, larids, alcids.

The primary objective of the census program in the migratory bird sanctuaries on the Lower North Shore of the Gulf of St. Lawrence (Figure 1) is to measure changes in the seabird community. Follow-up censuses have been carried out regularly since the first census in 1925 (Lewis 1925, 1931, 1937, 1942; Hewitt 1950; Tener 1951; Lemieux 1956; Moisan 1962; Moisan and Fyfe 1967; Nettleship and Lock 1973; Chapdelaine 1980; Chapdelaine and Brousseau 1984, 1991), providing a measure of the effectiveness of the Canadian Wildlife Service's conservation and protection programs. Furthermore, the results provide an indication of the health of the marine ecosystem, as seabirds play a central role in various trophic levels (Croxall 1987; Cairns et al. 1991) and population fluctuations in the different species may reflect food abundance or scarcity in the habitats exploited (Montevecchi 1993).

The purpose of this article is to present the results of the 1993 census and compare the population levels found with those obtained in the 1988 census. The census focused on 15 seabird species found in the sanctuaries on the North Shore of the Gulf of St. Lawrence (see Table 1 for the scientific names of the birds surveyed).

Methods

The census procedures used were essentially the same as those employed in the 1988 census (Chapdelaine and Brousseau 1991), and are summarized below:

Gaviids — We (see Acknowledgments) conducted a systematic count of Red-throated Loon nests around the ponds on the islands in each sanctuary.

Hydrobatids — We conducted a systematic count of active burrows. A burrow was considered active if the observer could see an egg (a rare occurrence) or found signs of excavation at the entrance of a burrow giving off the oily odour characteristic of petrels.

Anatids — The methods used depended on the size and number of islands in each sanctuary. On the Corossol Island sanctuary, we used a quadrat system, from which we extrapolated an average density (nests/ha) for the entire area deemed suitable for the nesting of Common Eiders. In sanctuaries with a large number of islands and islets, such as Watshishou and Ile à la Brume, we counted all the nests on at least 30% of the land area and extrapolated an average density over the entire area of all the islands. We conducted systematic nest counts in the Iles Sainte-Marie, Île aux Perroquets and Baie des Loups sanctuaries. In the Betchouane sanctuary, we made a systematic count of the nests on Calculot Island, but on Innu Island we used a scheme involving unequal sized sample units (*see* Caughley 1977), counting all the nests within a series of evenly spaced, 16-m-wide transects.

Phalacrocoracids — We carried out systematic counts of Great Cormorant and Double-crested Cormorant nests. On Corossol Island, where Double-

FIGURE 1. Location of the sanctuaries of the North Shore of the Gulf of St. Lawrence.

crested Cormorants nest in a treetop colony in a stand of spruce tree, the counts were done from elevated lookouts.

Larids — In large colonies of Herring Gulls like the one found on Corossol Island, we sampled subcolonies where the number of nests (Np) and the number of adults (Ni) were determined. Then, using the factor k (k=Np/Ni), we estimated the number of pairs in sectors where we counted only the number of adults present. This method was also used in the Watshishou, Île à la Brume and Baie des Loups sanctuaries, where nests were very scattered. Elsewhere, we made a systematic count of all nests. In the case of the Great Black-backed Gull, we counted the adults present only in the colonies. For the Ring-billed Gull, which was found nesting in small numbers only in the Île à la Brume and Baie des Loups sanctuaries in 1993, we counted all the nests. We also counted all the nests of Common and Arctic terns but combined the results for the two species (see Table 1), which are difficult to distinguish and very often nest side by side in mixed colonies. In the case of the Black-legged Kittiwake, we counted all the nests occupied by adults.

Alcids — We carried out a systematic count of eggs in the Razorbill and Common Murre colonies that could be accessed. However, Razorbills frequently nest in habitats adjacent to Common Murre colonies, which are currently expanding. Both species are very susceptible to disturbance and, to minimize the impact on these colonies, we counted individuals in attendance at the colonies and on adjacent water from a distance. This procedure was used mainly in the Îles Sainte-Marie Sanctuary, home to 82% of the Common Murre population on the Lower North Shore. The Black Guillemot population was estimated from adult bird counts around the islands. For the Atlantic Puffin, a systematic count of active burrows was carried out in the colonies in the Betchouane, Îles Sainte-Marie and the Îles aux Perroquets. On Blacklands Island in the Baie des Loups sanctuary, which is home to 90% of the sanctuary's Atlantic Puffin population, we used the factor k method described above for larids; elsewhere in the sanctuary, we counted active burrows. On the Île aux Perroquets in the Baie de Brador sanctuary, we employed evenly spaced grids and line transects and used the method described by Chapdelaine and Brousseau (1984) to extrapolate populations. On

TABLE 1. Census of seabirds (number of individuals) in the bird sanctuaries of the North Shore of the Gulf of St. Lawrence 1988 and 1993.

	Île du Corossol		Betchouane		Watshishou		Île à la Brume		Baie des Loups		Îles aux Perroquets		Îles Sainte-Marie		Baie de Brador		Total	
Species	1988	1993	1988	1993	1988	1993	1988	1993	1988	1993	1988	1993	1988	1993	1988	1993	1988	1993
Red-throated Loon																		
Gavia stellata							6	2	6	10	20	10	44	44			76	66
Leach's Storm Petrel																		
Oceanodroma leucorhoa	1474	1614							208	226	6		56				1744	1840
Great Cormorant																		
Phalacrocorax carbo													86	78			86	78
Double-crested Cormorant																		
Phalacrocorax auritus	2938	1278			282	714							1338	1480			4558	3472
Common Eider																		
Somateria mollissima	130	1010	3260	4872	2074	4444	608	1072	846	1392	362	560	1256	1198			8536	14548
Ring-billed Gull																		
Larus delawarensis					18		270	28		76							288	104
Herring Gull																		
Larus argentatus	11296	1224	1380	1006	207	964	458	164	672	404	660	174	1520	860	2	83	16195	4879
Great Black-backed Gull																		
Larus marinus	804	662	42	112	365	338	84	28	280	320	96	96	210	518	2	210	1883	2284
Black-legged Kittiwake																		
Rissa tridactyla	8072	5898	128	144							136	120	200	132			8536	6294
Caspian Tern																		
Sterna caspia							15										15	0
Common and Arctic Terns																		
Sterna hirundo } *Sterna paradisaea*			39		890	260	295	113	4	34	34	72	88	66			1350	545
Common Murre																		
Uria aalge	211	280							10	8	7471	5233	18357	25308			26049	30829
Razorbill																		
Alca torda	590	589	82	142	6		7	8	242	241	2461	3113	2848	3342	800	954	7036	8389
Black Guillemot																		
Cepphus grylle	151	99	2		15	13	26	74	53	75	96	47	178	101		2	521	411
Atlantic Puffin																		
Fratercula arctica			226	276					9030	13834	3494	3354	5306	5650	17066	23570	35142	46684
Total	25666	12654	5159	6552	3857	6733	1769	1489	11351	16620	14836	12779	31487	38777	17890	24819	112015	120423

Greenly Island in the same sanctuary, we conducted a systematic count of active burrows.

Results

The total number of birds in the eight sanctuaries visited in 1993 was 7.5% higher than in the 1988 census. Numbers were up for Leach's Storm-Petrels, Common Eiders, Great Black-backed Gulls, Common Murres, Razorbills and Atlantic Puffins, while they were down — slightly or sharply — for Red-throated Loons, Great Cormorants, Double-crested Cormorants, Ring-billed Gulls, Herring Gulls, Black-legged Kittiwakes, Caspian Terns, Common Terns, Arctic Terns and Black Guillemots. The decline was dramatic in the case of the Caspian Tern and Herring Gull.

The Corossol Island sanctuary was censused on 4 and 5 June. A 51% decrease in the total number of birds was observed, due in large part to the major decline in the Herring Gull population from 11 296 to 1224 individuals and, to a lesser extent, to the decline in the Black-legged Kittiwake population from 8072 to 5898 individuals. Other populations on the decline included the Double-crested Cormorant, Great Black-backed Gull and the Black Guillemot. The most important increase occurred in the Common Eider population, which rose from 130 to 1 010 individuals. The Common Murre, which was reported nesting here for the first time in 1972 (Nettleship and Lock 1973), has continued to increase since 1988, even occupying new ledges. Aside from the species traditionally found in this sanctuary, we also discovered a pair of Northern Fulmars (*Fulmarus glacialis*) on a grassy ledge on the southeastern part of the island. Although we did not find any eggs, their prospecting behaviour suggested they could eventually nest on Corossol Island, which would be the first breeding record for the species in the Gulf of St. Lawrence.

We visited the Betchouane Bird Sanctuary on 7 and 8 June. The Common Eider population continued to expand after the striking increase reported in the 1988 census (Chapdelaine and Brousseau 1991), rising from 3260 individuals in 1988 to 4872 individuals in 1993. This sanctuary consists of two islands, Innu Island and Calculot Island. Over 80% of Common Eider nests were found on Innu Island in a Black Spruce forest, a habitat similar to that found on Bicquette Island in the St. Lawrence estuary (Reed 1973), where the current population is 10 000 nests (CWS, unpublished data, 1994). This type of habitat is ideal for the development of large Common Eider colonies. Great Black-backed Gull, Black-legged Kittiwake, Razorbill and Atlantic Puffin numbers also increased in this sanctuary. The Herring Gull population experienced the greatest decline. The Black Guillemot, which was observed in 1988 but not in 1993, is not a typical species here.

The Watshishou Bird Sanctuary, which we censused on 9 June, consists of a chain of islands and islets dotted over more than 20 kilometres. The sanctuary is traditionally known for its Common Eider population (Lewis 1925). The Double-crested Cormorant, Common Eider and Herring Gull populations all increased substantially. The most significant declines were in the Common and Arctic tern populations. Also notable was the total absence of Razorbills, although the general habitat found in the

TABLE 2. Changes in the numbers of seabirds in sanctuaries on the North Shore of the Gulf of St. Lawrence, Québec, 1982 to 1993.

	Years of survey			Compound annual growth* rate by period	
Species	1982	1988	1993	1982-1988	1988-1993
Red-throated Loon	68	76	66	1.87%	-2.78%
Leach's Storm Petrel	234	1744	1840	39.76%	1.08%
Great Cormorant	134	86	78	-7.12%	-1.93%
Double-crested Cormorant	1353	4558	3472	22.44%	-5.30%
Common Eider	2410	8536	14548	23.46%	11.25%
Ring-billed Gull	945	288	104	-17.97%	-18.43%
Herring Gull	18843	16195	4879	-2.49%	-21.33%
Great Black-backed Gull	1722	1883	2284	1.50%	3.94%
Black-legged Kittiwake	7506	8536	6294	2.17%	-5.91%
Caspian Tern	7	15	0	13.54%	-100.00%
Common and Arctic Terns	1935	1350	545	-5.82%	-16.59%
Common Murre	14615	26049	30829	10.11%	3.43%
Razorbill	3572	7036	8389	11.96%	3.57%
Black Guillemot	484	521	411	2.73%	-4.63%
Atlantic Puffin	30466	35142	46684	2.41%	5.84%

$$^{*}r = \frac{\log_e N(t) - \log_e N(o)}{t} \; 100\%$$

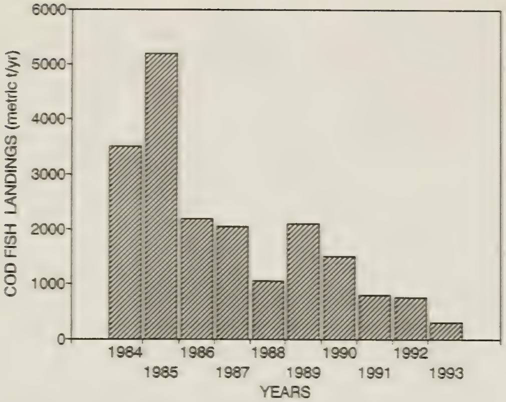

FIGURE 2. Cod fish landings in harbors of the North Shore of the Gulf of St Lawrence in 1984-1993. Data supplied by Fisheries and Oceans Canada, Mont-Joli (Québec).

populations. Also notable was the total absence of Razorbills, although the general habitat found in the sanctuary is not ideal for this species.

The Île à la Brume Bird Sanctuary (visited on 13 June) had the smallest number of birds overall (1489 individuals) which represents only 1% of the total population in the eight sanctuaries in 1993. Since the disappearance of the Caspian Tern population, the sanctuary no longer holds the interest it once did for ornithologists. Significant declines were observed in Ring-billed Gull, Herring Gull, Great Black-backed Gull, Common Tern and Arctic Tern populations. Common Eider and Black Guillemot populations are increasing and the sanctuary's small Razorbill population has remained stable.

The Baie des Loups Bird Sanctuary, which we censused on 14, 15 and 16 June, was flourishing. Increases were observed in the Red-throated Loon, Common Eider, Ring-billed Gull, Great Black-backed Gull, Common Tern, Arctic Tern, Black Guillemot and Atlantic Puffin populations. The increase was particularly striking in the case of the sanctuary's Atlantic Puffin population, which accounts for 30% of the total Atlantic Puffin population on the North Shore.

We visited the Îles aux Perroquets Bird Sanctuary on 19 and 20 June. The total number of birds in the sanctuary was down by roughly 14%. This decrease was due mainly to the decline in the Common Murre population, which fell from 7471 to 5233 individuals, as well as to declines in the populations of Red-throated Loons, Leach's Storm Petrels, Herring Gulls, Black-legged Kittiwakes, Black Guillemots and Atlantic Puffins. Several species, including the Common Eider and Razorbill, increased.

The Îles Sainte-Marie Bird Sanctuary, which we visited on 12, 16, 17, 18, 20, 21 and 22 June, is still the largest on the North Shore both in terms of the number of birds and species diversity. The total bird population increased by about 23% in relation to 1988, the most striking increases occurring in the Great Black-backed Gull, Common Murre, Razorbill and Atlantic Puffin populations. A downward trend was observed in the Leach's Storm Petrel, Great Cormorant, Common Eider, Herring Gull, Common Tern, Arctic Tern and Black Guillemot populations.

The Baie de Brador Bird Sanctuary was censused on 26 and 28 June. Île aux Perroquets, which lies within the sanctuary, contains the largest Atlantic Puffin colony on the North Shore, accounting for 50% of the North Shore population. The puffin population on the island rose from 7988 pairs in 1988 to 10 817 pairs in 1993. The Greenly Island population also increased, from only 555 pairs in 1988 to an estimated 968 pairs in 1993. Significant increases in Herring Gull and Great Black-backed Gull populations were also observed, which is quite an unusual development where no more than a dozen individuals of each species had been recorded in the sanctuary since 1925.

Discussion

Our results indicated a general increase in the numbers of seabirds in the North Shore sanctuaries between 1988 and 1993. However, the rate of increase was smaller than that recorded for 1982-1988 (Chapdelaine and Brousseau 1991). As Table 2 shows, from 1988 to 1993 the greatest annual growth rates occurred in the Common Eider population, followed by the alcids (Atlantic Puffin, Razorbill and Common Murre). However, except for the Atlantic Puffin, these increases were less significant than in 1982-1988. Larid populations (*Larus* spp., *Sterna* spp. and *Rissa tridactyla*) declined sharply between 1988 and 1993, except for the Great Black-backed Gull.

Between 1988 and 1993, conservation efforts continued in the sanctuaries. These involved both vigorous enforcement programs and efforts to educate local communities about wildlife conservation (*see* Chapdelaine and Brousseau [1991] and Blanchard [1984]). The Baie des Loups, Îles Sainte-Marie and Watshishou sanctuaries were targeted for special attention, and the increase in seabird populations in these sanctuaries could be partly due to the sustained surveillance efforts there.

A dramatic drop in Herring Gull numbers was observed in all the North Shore sanctuaries except Watshishou and Baie de Brador, where it must be noted populations are very small compared to the large population that was found on Corossol Island in 1988 (see Table 1). This general decline may be related to the decreased commercial fishing activity in the region, particularly that involving Atlantic Cod (*Gadus morhua*) (Figure 2), which is the main fishery in this part of the Gulf (Chadwick and

Sinclair 1991). This fishery has traditionally provided substantial amounts of fish offal, a main food source for the gulls, and their breeding performance between 1988 and 1993 may have been affected by the reduced availability of this food. However, this association is only conjecture on our part as the actual role of fish offal in seabird population dynamics has never been studied (Hudson and Furness 1988; Watson 1981). Another opportunistic species, the Black-legged Kittiwake, may also have been affected by the decline in fishing as it too feeds on fish offal (Cramp et al. 1974; Watson 1981), though to a lesser extent than the Herring Gull.

Alcids now make up almost 72% of the total seabird population in the sanctuaries, compared to 56% in 1977 (Chapdelaine 1980). Researchers have suggested that an abundant food supply — in the form of sand lance (*Ammodytes* spp.) and capelin (*Mallotus villosus*), the main prey items of the alcids — may have a positive effect on breeding performance (Chapdelaine and Brousseau 1991). Research on the diet and reproductive success of the Razorbill between 1990 and 1992 on the St. Mary Islands reveals that feeding opportunities are currently excellent, with net productivity remaining around 73% during this period (Chapdelaine and Brousseau, in press), compared with a rate of only 61% in 1978. Razorbill populations are currently increasing, a trend that was not evident in 1978 (Chapdelaine and Laporte 1982).

A number of factors may be at work, however, in the dynamics of seabird populations. Because few specific studies have been carried out on seabird species' diet (quantity and quality of food), reproduction and annual adult and immature survival rates, the fluctuations observed in the populations of the various species between 1988 and 1993 cannot be convincingly explained.

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Range Expansion of Coyotes, *Canis latrans*, Threatens a Remnant Herd of Caribou, *Rangifer tarandus*, in Southeastern Québec

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The autumn calf:cow ratio of a remnant Caribou herd in Gaspésie Park, Québec, declined from ≈ 20-30 calves per 100 females in 1984-1985 to only four in 1987, after Coyotes colonized the area. Twenty adult female Caribou were radio-tagged in November of the same year, and examination of blood samples and vaginal swabs did not detect diseases likely to affect fecundity. The following spring, 13 of 19 (68%) radio-collared Caribou were observed to be followed by a calf at the time of parturition, but only one neonate survived until the following autumn. In 1989 and 1990, 25 radio-tagged calves were monitored and 16 of them died in the course of the summer. Likely cause of death was determined for 11 cases and suggested that Coyotes were responsible for 7 deaths, Black Bears for 3 and Golden Eagle for 1. The mortality rate of neonates was higher for the Caribou group inhabiting the eastern portion of the park than for the other group which used the centre of the park. Calves surviving until autumn exhibited low mortality during their first winter of life: 8 of 9 survived this season during three winters. Between 1987 and 1992, annual survival of adults exceeded 0.90 on average; most deaths occurred during the harsh winter of 1990-1991, and Coyote predation was possible in a maximum of two of six cases. Predators were reduced in the park and surroundings between 1990 and 1992 in order to improve calf survival. Recruitment was sufficient to replace mortality after 1988 for the Caribou group occupying the centre of the park, but it remained at about 10 calves:100 females until 1992 for the group inhabiting the eastern part of the park, at which time calf survival finally improved.

Le nombre de faons par 100 femelles à l'automne dans la population relique de caribous du parc de la Gaspésie chuta de ≈ 20-30 en 1984-1985 à seulement 4 en 1987, à la suite de la colonisation de l'endroit par les coyotes. Vingt femelles adultes furent munies d'un collier émetteur en novembre de la même année et l'examen d'échantillons de sang et d'écouvillons vaginaux ne révéla aucune présence d'infections susceptibles d'affecter la fécondité. Au printemps suivant, 13 des 19 caribous encore sous suivi télémétrique furent observés suivis d'un faon au moment de la mise bas; un seul de ces nouveau-nés survécut jusqu'à l'automne suivant. En 1989 et 1990, 25 faons furent marqués d'un collier émetteur à la naissance et ils furent suivis quotidiennement jusqu'à la mi-juillet; 16 d'entre eux périrent au cours de l'été. Des indices trouvés au site de 11 décès suggérèrent fortement que le coyote était responsable de la mort dans 7 cas, l'ours noir dans 3 et l'aigle royal dans 1. Le taux de mortalité des faons était plus élevé dans le groupe de caribous fréquentant l'est du parc que dans celui utilisant le centre. La survie des faons était meilleure au cours de leur premier hiver: 8/9 survécurent au cours de cette saison pendant 3 hivers différents. Entre 1987 et 1992, la survie annuelle des adultes excéda 0.90 en moyenne; la plupart des mortalités survinrent au cours de l'hiver très rigoureux de 1990-1991, et le coyote pourrait avoir été impliqué au plus dans 2 cas sur 6. Des prédateurs furent retirés du parc et des environs entre 1990 et 1992 afin d'améliorer la survie des faons. Le recrutement était suffisant pour assurer le remplacement des mortalités dans le groupe de caribous occupant le centre du parc après 1988, mais il demeura autour de 10 faons: 100 femelles dans le groupe de l'est jusqu'en 1992, alors qu'il s'est finalement redressé.

Key Words: Caribou, *Rangifer tarandus*, Coyote, *Canis latrans*, population dynamics, Gaspésie Park, Québec.

In recent times, the southern boundary of Caribou (*Rangifer tarandus*) distribution within North America has shifted north (Banfield 1977; Kellsall 1984). In the Northeast, Caribou occupied the Maritime Provinces and northern New England before colonization by Europeans (Banfield 1961). Caribou disappeared from Prince Edward Island in 1874, from Nova Scotia in 1925, and from New Brunswick in 1927 (Banfield 1961). The Caribou herd inhabiting Gaspésie Park in southeastern Québec represents the last population of this species still persisting on continental North America south of the Fleuve Saint-Laurent. For this reason, it was classified as threatened in 1984 (Kelsall 1984), a decision later supported by examination of transferrin alleles that suggested isolation from adjacent Caribou populations (Roed et al. 1991). Many factors may have contributed to the shrinkage of the Caribou range, including habitat loss to agriculture, logging and urbanization, predation, hunting by humans, climatic changes, and the meningeal worm (*Parelaphostrongylus tenuis*) brought by range extension of White-tailed Deer (*Odocoileus virginianus*)(Bergerud 1974; Bergerud and Mercer 1989; Crête and Payette 1990).

Coyote (*Canis latrans*) distribution was confined to central and southwestern North America at the

time of first European settlements. It expanded northward, southward and eastward, beginning in the middle of the nineteenth century (Nowak 1979). Coyote arrival is recent in the Northeast; the species was first observed in Québec in 1944 and it reached the island of Newfoundland in 1985 (Larivière and Crête 1993). The clearing of forests for agriculture that created suitable habitats, the elimination of wolves (*Canis lupus*; *C. rufus*) as major competitors, and hybridization with wolves (Nowak 1979; Lehman et al. 1991) may have all contributed to the range extension of the Coyote. Eastern Coyotes are larger than western conspecifics (Thurber and Peterson 1991; Larivière and Crête 1993), probably because of genetic differences (Nowak 1979; Larivière and Crête 1993), a characteristic which enhanced their ability to prey on adult White-tailed Deer in winter. This new prey was probably important in the successful colonization of Coyote through northeastern North America (Larivière and Crête 1993). White-tailed Deer had previously benefitted from the extirpation of wolves from the southern portion of Québec at the turn of the last century, and expanded their range before Coyote arrival (Martin 1980), although populations fluctuated with winter severity.

No quantitative information exists on Caribou distribution and abundance on the Gaspé peninsula in eastern Québec at the beginning of the century, but they were apparently abundant as hunting was allowed until 1949. A first aerial survey in 1953 produced an estimate of 500-1000 Caribou (Moisan 1957). The occupied area diminished in size thereafter, and the herd probably decreased until the mid-1970s, stabilizing at about 200-250 individuals (Crête et al. 1994). During the annual aerial composition counts conducted in autumn, the low percentage of calves observed in 1987, i.e., 2% or 4 calves:100 females, attracted managers' attention. This unexpected decline in recruitment justified research on the causes of such a low calf:cow ratio, and led to a recovery plan, enforced since 1990, that included predator control (Crête et al. 1994).

In this report, we describe the demography of Caribou during Coyote colonization of Gaspésie Park, two species that probably had limited contact on an evolutionary timescale. We also evaluate the chances and conditions for Caribou survival in relation to Coyote predation.

Study Area

The study area included Gaspésie Park and parts of Chic-Chocs Game Reserve in the centre of Gaspé Peninsula (Figure 1). Exploitation of natural resources is not allowed in the park and logging ceased in 1977, but timber harvesting continues in the game reserve. The relief is relatively pronounced and ranges from 60 m in the valley bottoms to 1268 m for Mont Jacques-Cartier and to 1154 m for Mont Albert. The climate is continental but strongly influenced by the proximity of the Gulf of the Saint-Lawrence and by altitude. The temperature of the coldest (January) and the warmest (July) month averages -19°C and 11°C on Mont Logan (1128 m), compared to -10°C and 18°C, respectively at sea level (Gagnon 1970). Annual precipitation averages 1663 mm on Mont Logan, 33% of which is snow; corresponding precipitation at sea level is 854 mm and 32%. At high altitude, snow persists from October to June, whereas the snow period lasts two months less in the valley of Rivière Sainte-Anne.

The boreal forest covers most of the study area, with the exception of the highest elevations where it is replaced by a small belt of forest-tundra and alpine tundra (Boudreau 1981; Figure 1). The tundra is continuous on Mont Albert, but is fragmented on the McGerrigle Mountains, that include Mont Jacques-Cartier. Major tree species are Balsam Fir (*Abies balsamea*), White and Black spruce (*Picea glauca*; *P. mariana*); at lower elevation and in burned over areas, Paper Birch (*Betula papyrifera*), Trembling Aspen (*Populus tremuloides*) and Balsam Poplar (*P. balsamifera*) are common.

Large mammals present in the park include: Caribou, White-tailed Deer, Moose (*Alces alces*), Black Bear (*Ursus americanus*), Canada Lynx (*Lynx canadensis*) and Coyote. Gray Wolves were once present on the Gaspé Peninsula, but were exterminated by the turn of the last century (Martin 1980). Coyotes were first mentioned on the peninsula in 1973 (George 1976). They appeared in the park in the early 1980s and were common during the study period, i.e. 1987-1992. Black Bear density ranged between 0.03-0.06 individual $\cdot km^{-2}$ in the study area during the summer of 1990 (Boileau et al. 1994); bears appear not to be attracted to alpine tundra although some animals included such habitat in their home range (Boileau et al. 1994). White-tailed Deer were common in the park during the first half of the 1980s and they used a 22-km^2 wintering area in the Rivière Sainte-Anne valley. The winter yard was reduced to 1.5 km^2 in 1990 following severe winters, and deer were rare in the park at the time of this study (Ministère de l'Environnement et de la Faune, unpublished). No data exist on lynx abundance, but they appeared common in the park, based on track abundance and accidental captures when live trapping Coyotes. Seventy Coyotes were removed from the park between 1990 and 1992. Thirty-seven Black Bears were also removed from the alpine tundra in 1990 and 1991.

Visitors to Gaspésie Park come mainly for cross-country skiing in winter and for hiking in summer. Approximately 8000 persons climb Mont Jacques-Cartier annually, and probably slightly less in the case of Mont Albert, but exact figures are unavailable (F. Boulanger, personal communication).

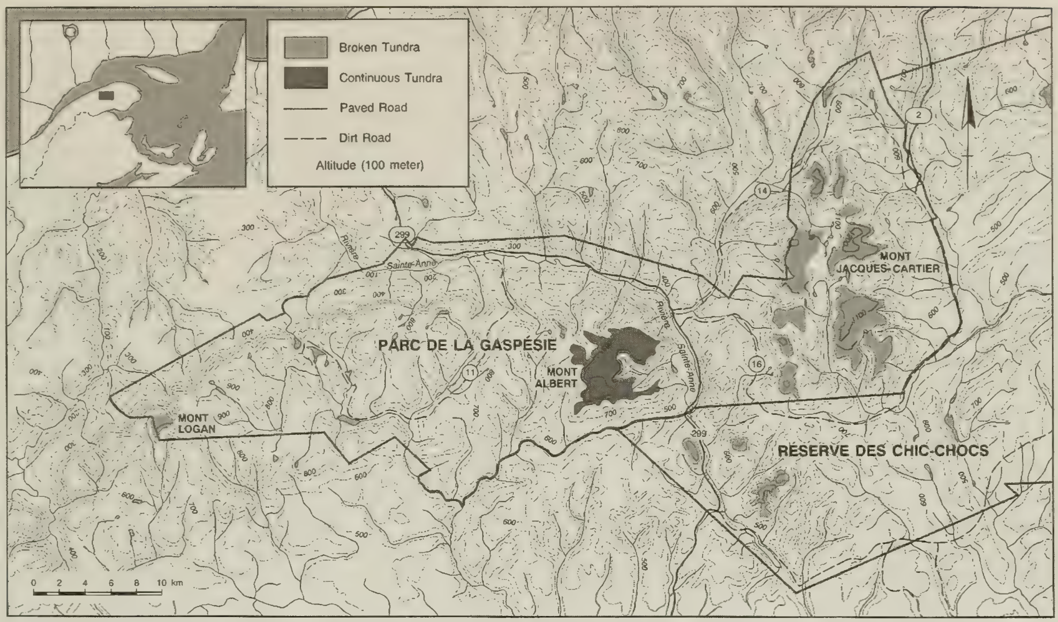

FIGURE 1. Location of Gaspésie Park in eastern Québec and alpine tundra in the park. The countinuous tundra is used by the Mont Albert Caribou group and the broken one by the Mont Jacques-Cartier group.

Methods

In November 1987, 20 adult female Caribou, (three adult males and one calf) were captured with a net gun (Potvin and Breton 1988) and fitted with radio-collars containing mortality sensors, in near equal numbers on Mont Jacques-Cartier and on Mont Albert. A blood sample was drawn from 19 animals; vaginal (n=13) or prepucial (n=2) swabs were also taken when possible and all animals were examined to evaluate their general physical condition (Patenaude 1988). Antibodies of *Brucella abortus*, *Leptospira pomona*, *L. icterohaemorrhagiae*, *L. grippotyphosa*. *L. hardjo*, *L. bratislava*, Infectious Bovine Rhinotracheitis, Bovine Viral Diarrhea, Parainfluenza 3, Bovine Adenovirus and Respiratory Suncytial Virus were tested using serum samples. In addition, bacteriological cultures of vaginal and prepucial swabs were done. In the spring of 1989, eight additional adult females and 14 newborn calves were equipped with transmitters. Eleven additional calves were captured and equipped with transmitters in 1990. No measurements nor samples were taken on calves in order to prevent separation from their mother (Ballard et al. 1979). The radio-collars of three calves captured at birth in 1989 were replaced when they were 10–12 months old. Radio-tagged Caribou were monitored irregularly from aircraft between August and May, beginning in December 1987, with an average of one location per animal per month. However, monitoring of calves from helicopter was daily from late May to mid-July in 1989 and 1990. Monitoring ceased in March 1992.

When a radio-collar transmitted in mortality mode, it was recovered and the cause of death determined when possible. For adults, carcasses were often first visited long after death, but their position and signs left in snow made it occasionally possible to speculate about the cause of death. As predation was suspected to be involved in most calf deaths, a meticulous inspection of all sites was done (Ballard et al. 1979; Larsen et al. 1989). We looked for predators and their tracks, scats or hair near carcasses. We also estimated the proportion of skin remaining and we noted whether carcasses were hidden, two behaviours typical of bear predation. When carcass remains were dispersed, we suspected that Coyotes made the kill.

Data on the composition of the herd in autumn were collected sporadically, starting in 1953. During early censuses, animals were classified from the ground as calves or adults, and from helicopter beginning in 1984. The tundra habitat ($\approx$75 km^2) was flown at 100-120 km•h^{-1} and at an altitude of $\approx$100 m above the ground, and all visible Caribou were counted, aged as calf or older based on their size and the shape of the head, and sex determined from antler size and vulval patch. The number of animals with radio-collars was also noted after 1987, but individuals were not identified. A complete census lasted 4-5 h and, in some

years, up to three surveys were carried out in October and/or November.

Corrected independent population estimates were made for the Mont Albert and Mont Jacques-Cartier groups, using the proportion of radio-tagged females observed during composition counts to estimate the proportion of all females seen. Variance of correction factors was estimated with the binomial distribution. As contact was lost with some radio-tagged animals, it was impossible to determine if such radio-collars were broken but still observable on living Caribou during censuses, or if they were removed from the study area, and undetectable during surveys. We considered two scenarios: (1) radio failure but collar still present on a living animal, and (2) death of the animal and radio on the ground or removed from the study area. The first alternative produced maximum population estimates while the second yielded minimum ones. When two surveys were carried out during the same autumn, we used the more precise estimate.

We estimated the demographic trend of the herd, based on productivity and mortality rates observed during the course of this study. Number of female Caribou in the population was estimated by age class from 1983 to 1992. The smoothed age structure calculated by Messier et al. (1988: Table 5) served as initial age distribution in 1983 because reproduction appeared relatively stable in previous years. Observed annual survival rate of radio-tagged females was used for all age classes between 1987 and 1992, and the average for this period was utilized for years without telemetry data (0.92 and 0.93 for the Mont Albert and Mont Jacques-Cartier group, respectively). Survival rate was assumed to be 0 for the last age class, i.e. 15 year-olds. Recruitment was estimated from calf:cow ratios observed during autumn composition counts, after summer mortality occurred. Female population size was set at 40 and 45 individuals in autumn 1987 for the Mont Albert and Mont Jacques-Cartier groups, respectively. We also made predictions for future demographic trends, given variable calf:cow ratios in autumn and adult survival rates. The calculated age distribution obtained in 1992 served as the starting point for simulating future trends. No density-dependent mechanisms were included in the model. We used the computer program Simcon adapted for IBM-PC (C. Walters, University of British Columbia) for the simulations.

Results

The percentage of calves in the Gaspésie Park Caribou population in autumn averaged 17.6% (n = 1573) prior to the arrival by Coyotes (1953-1983), declined to 4.5% (n = 1652) after colonization by Coyotes (1984-1989), but increased to 13.4% (n = 372) following implementation of a Caribou recovery plan in 1990-1992 (χ^2=39.8; 3 d.f.; P<0.005). The decline in recruitment was not initiated in the same years, nor did it have the same intensity on Mont Albert and Mont Jacques-Cartier (Figure 2). Recruitment declined in 1985 on the former, but remained moderate until 1987 on the latter. The decline in recruitment was less on Mont Albert where recovery began in 1989, compared to 1992 for the other group of Caribou.

All tests for diseases likely to affect Caribou fecundity proved to be negative for animals captured in autumn 1987 (Patenaude 1988). During parturition 1988, a minimum of 5 of 9 adult female Caribou on Mont Albert and 8 of 10 on Mont Jacques-Cartier were observed accompanied by newborn calves. During spring 1990, we closely monitored parturition and found that all 11 radio-collared females on Mont Albert produced a calf, in comparison with 6 of 7 on Mont Jacques-Cartier. Only 1 of the 13 calves produced by radio-tagged females in 1988 was still alive in July on Mont Albert and it survived until autumn. On Mont Albert, 4 of 7 collared calves died in 1989 and 2 of 7 in 1990. All seven calves radio-tagged on Mont Jacques-Cartier in 1989 died during summer, and 3 of 4 died the following summer.

As there was a positive linear relationship (r^2=0.94; P < 0.01; df=4) between the survival rate of monitored calves of both Caribou groups in 1988, 1989 and 1990, and the number of calves per 100 females counted in autumn in respective groups, we considered our samples representative of the general

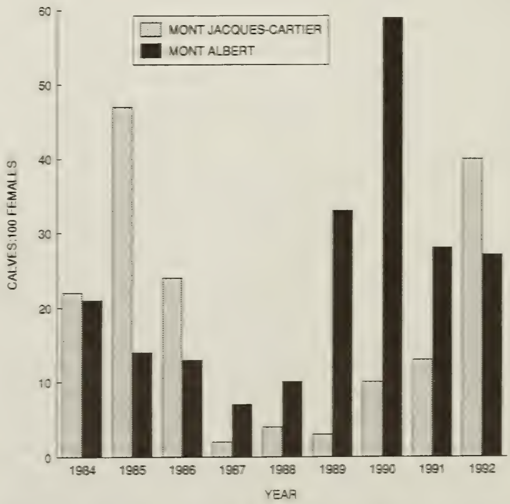

FIGURE 2. Number of Caribou calves per 100 females censused in helicopter during autumn composition counts in the alpine tundra of Gaspésie Park, according to two sub-populations.

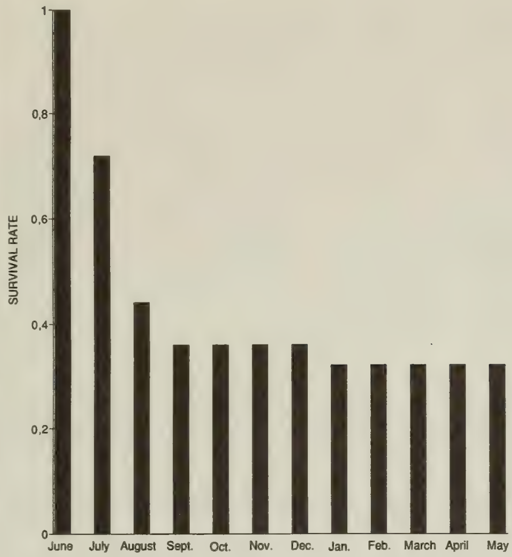

FIGURE 3. Cumulative survival rate during the first year of life of 25 Caribou calves radio-tagged at birth in Gaspésie Park, Québec, in 1989 and 1990. Births were assumed to occur on 1 June.

population. Mortality rate of calves was greatest during the weeks following birth, but calf loss continued throughout the summer (Figure 3). In contrast, only one out of nine calves monitored during the winter died from an unknown cause. It was often difficult to determine the cause of death with certainty, even during the period when we monitored collared calves daily, because few remains were left. Coyotes were suspected in 7 of 11 cases: they were observed near the kill on two occasions, tracks were visible twice, hair was found once, and remains were dispersed in two cases. Death was attributed to Black Bears in three cases: twice, a bear was seen in the vicinity of the carcass with scats present, and the carcass was hidden on one occasion. In another case, a Golden Eagle (*Aquila chrysaëtos*) was observed feeding on a freshly killed calf but an autopsy was not performed to confirm if the bird killed the animal. We had no indication as to the cause of the remaining five deaths, either because no sign was present near the recovered collars or because of extended time between death and radio recovery. We observed a single Coyote chasing a group of female Caribou and their calves on Mont Albert in late May 1990. A Black Bear killed on Mont Jacques-Cartier during the same period had newborn cervid hair in its stomach while a female Caribou stood near the bear when first seen.

Between 1987 and 1992, survival was high for radio-tagged adult Caribou, with the exception of the 1990-1991 winter (Table 1). One female died in an avalanche at Mont Albert in 1988. Another female dispersed 50 km south of Mont Jacques-Cartier and was found dead by a forest worker in July 1991. It was assumed to have died during winter of 1990-1991. During winter 1990-1991, when snow depths were exceptionally high, four adult females died: one from falling off a cliff in May at Mont Albert and another one from an unknown natural cause at Mont Jacques-Cartier. In the latter instance, the carcass was found intact under a Balsam Fir tree. Although Coyotes visited the remaining two carcasses, we remained uncertain if they killed the Caribou or were scavenging, although predation was suspected in one case. Overall, the unweighted annual survival rate of yearlings and older females averaged 0.92 on Mont Albert and 0.93 on Mont Jacques-Cartier between 1987 and 1991.

TABLE 1. Survival of radio-collared female Caribou during the snow-free period and the winter according to their age, year and the sub-population (Mont-Jacques-Cartier: JC; and Mont Albert: A) in Gaspésie Park, southeastern Québec.

	June-October		November-May		Annual	
	JC	A	JC	A	JC	A
Adults						
1987-1988	1.00 (0[a]; 9[b])	1.00(0; 9)	1.00(0; 10)	0.90(030; 10)	1.00(0[a])	0.90(0.10)
1988-1989	1.00 (0; 8)	1.00(0; 13)	1.00(0; 8)	1.00(0; 9)	1.00(0)	1.00(0)
1989-1990	1.00 (0; 8)	1.00(0; 13)	1.00(0; 8)	1.00(0; 13)	1.00(0)	1.00(0)
1990-1991	0.83 (0.16;6)	1.00(0; 13)	0.87(0.12; 8)	0.76(0.12; 13)	0.73(0.16)	0.77(0.11)
1991-1992	—	—	1.00(0; 6)[c]	1.00(0; 11)[c]	—	—
Yearlings						
1988-1989	—	1.00(1[d])	—	0(1)	—	0.5(1)
1991-1992	—	1.00(3)	—	1.00(3)	—	1.00(3)

[a]S.E., according to Heisey and Fuller (1985)
[b]Number of radio-tagged animals at the beginning of the period
[c]Last census on 23 March 1992
[d]Number of individuals monitored

TABLE 2. Number of female Caribou over 1-year old observed during autumn helicopter censuses, visibility rate of radio-tagged animals, and estimated number of females in the Mont Jacques-Cartier and the Mont Albert group, 1988-1991.

	Mont Jacques-Cartier Group			Mont Albert Group		
Year	Females Censused	Visibility rate	Total number of females	Females censused	Visibility rate	Total number of females
1988	31	0.70(0.15[a]; 10[b])	44 (10[a]; 42[c])	22	0.56(0.18; 9)	39(13; 40)
1989	9	0.22 (0.15; 9)	41 (27; 36)	8	0.31(0.13; 13)	26(11; 24)
1990	20	0.78 (0.15; 9)	26 (5; 23)	29	0.75(0.11; 16)	39 (6; 36)
1991	32	0.71 (0.18; 7)	45 (12; 38)	25	0.69(0.13; 13)	36 (7; 28)

[a]S.E.
[b]n
[c]minimum estimate, assuming that all censored radio-collared Caribou were dead.

Population estimates using the fraction of radio-tagged Caribou seen during autumn composition counts produced imprecise results (Table 2). It was impossible to detect a trend in population size between 1988 and 1991, but during this period the four estimates suggested that there were about 40 females over one-year old on Mont Albert and slightly more on Mont Jacques-Cartier. Females comprised 38-56 percent of the herd in autumn based on aerial counts; we therefore estimated 150-250 caribou in the park during the period of study.

Discussion

Was Coyote predation the cause of low recruitment of Caribou observed in the study population between 1987 and 1992? Coyotes were suspected in 7 of 11 deaths of radio-collared calves. Although the sample size is small, it did represent 10-20% of the calves born in 1989 and 1990. The correlation between Coyote colonization of the park and decline in Caribou recruitment also suggests that Coyotes were the cause of decreased calf survival. Also, increased recruitment in recent years coincided with decreasing coyote abundance: trapping success (Coyotes captured/1000 trap-nights) during the caribou recovery plan averaged 7.3, 3.2, 1.0, 0.9 and 0.9 from 1990 to 1994 (R. Isabel, Ministère de l'Environnement et de la Faune du Québec, unpublished report). As well, the timing of deaths, which occurred throughout summer, also suggested that Coyotes were a major predator. In other studies of predation on cervid neonates by Black or Grizzly (*Ursus arctos*) bears and wolves, bears concentrated their kills soon after birth (Franzmann et al. 1980; Ballard et al. 1981; Boertje et al. 1988; Larsen et al. 1989; Osborne et al. 1991) while wolves continued to prey on calves throughout the summer (Larsen et al. 1989). Bears might be incapable of catching cervid neonates when they become more mobile after a few weeks of life (Ballard et al. 1980), or they could switch to other sources of food later in the summer. Before the mid-1980s, bears probably killed some Caribou neonates every year in Gaspésie Park. Golden Eagles may have also killed a few, but calf:cow ratios in autumn normally exceeded 30:100. Mortality from Coyotes was most probably additive and depressed recruitment to only four calves per 100 females in 1987.

No Caribou > 6 months were killed by Coyotes during 11 915 snow-free Caribou-days of telemetry monitoring, except for one animal that had a broken-leg at capture. During the winter of 1991, Coyotes may have killed a maximum of two radio-tagged females. This winter was the most severe between 1976 and 1992, as evidenced by the severity index for White-tailed Deer on the Gaspé Peninsula which exceeded the average by 66% (Breton 1992). Apparently, when Caribou attain 6 months of age, they become invulnerable to Coyote predation except perhaps during harsh winters. Body mass of female Caribou belonging to the subspecies *caribou* varies between 100 and 125 kg (Crête et al. 1993) when on a good range, which appears too large a prey for a predator averaging 14 kg for females and 16 kg for males in winter (Larivière and Crête 1993).

We made simulations to predict the fate of the two Caribou groups under a scenario of persistent predation without intervention, assuming that recruitment in autumn had remained at 10 calves:100 females (Figure 4). We used the same annual survival rate for all age classes (0.92 and 0.93) except the last one (0). New recruits were not sufficient to replace mortality in adults and both groups exhibited a finite rate of increase (λ) of 0.88. Under such a scenario, there would have been fewer than 10 females in each group by the year 2008 on Mont Albert and 2006 on Mont Jacques-Cartier. Recruitment in autumn had to be 27.5 calves:100 females for the population to remain stable (λ=1.0), when annual survival rate in animals older than 6 months was 0.92. With the objective of 30 calves:100 females as set in the recovery plan (Crête et al. 1994), λ would be 1.013 if the average survival rate of monitored caribou between 1987 and 1992 remained constant. Simulations suggested that recruitment in autumn had to reach 66

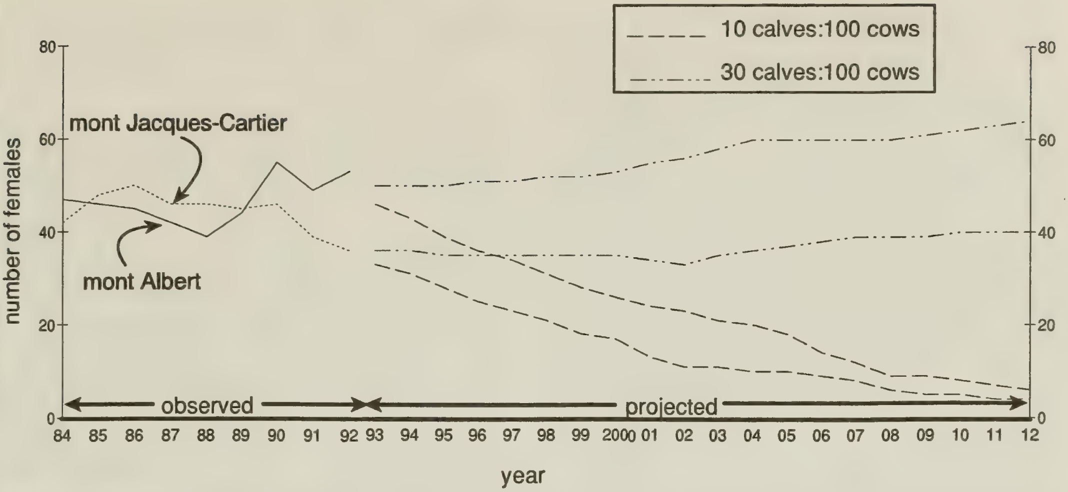

FIGURE 4. Simulated number of female Caribou making up the Mont Jacques-Cartier and the Mont Albert group in Gaspésie Park between 1984 and 1992, and projected population size up to 2012 according to two calf:cow ratios in autumn, assuming an annual survival rate of 0.92 for yearlings and older animals.

calves:100 females for a population to remain stable (λ=1.0) under an adult survival rate of 0.80.

Black Bear densities were reduced in the alpine tundra in 1990 and 1991, and Coyotes have been controlled since 1990 in the park, in accordance with the recovery plan (Crête et al. 1994). In addition, the hiking trail ascending Mont Jacques-Cartier has been closed until late June since 1992 because hikers affect Caribou behaviour (Dumont 1993). It is impossible to reach a conclusion on the role of predator removal with respect to enhanced recruitment. It is obvious that removal of predators will decrease mortality of prey, at least over the short term. Other studies on cervids have reported significant increases of neotate survival following predator control (e.g., Beasom 1974; Austin et al. 1977; Guthery and Beasom 1977; Gasaway et al. 1983; Ballard and Miller 1990). However, the magnitude of improved prey survival will depend on the proportion and the composition of the predator population removed. Efficiency of predator removal also depends on whether the offending predators are removed. Coyotes need approximately 2.1 kg of meat daily to sustain normal metabolic activities in the wild (Pekins and Mautz 1990). As Caribou calves weigh $\approx$7 kg at birth (Crête et al. 1993), a pair of Coyotes raising pups would need approximately 1 calf per day if they depended exclusively on Caribou calves for food. Bears need similar or greater meat consumption depending on the size of the individual (Cowan et al. 1957). This means that only a few bears and Coyotes could have been responsible for the measured mortality. Thus, predator control was successful only if those animals responsible were taken. Caribou may have altered their behaviour in response to Coyotes. This may have happened on Mont Albert where recruitment increased prior to predator removal. There, continuous tundra covers 24 km^2 and harassment by hikers is lower due to the position of trails, which could give caribou dams more opportunities to detect predators and to keep them at distance. This hypothesis is consistent with other studies (Bergerud et al. 1984; Seip 1992).

Permanent predator removal to ensure Caribou conservation is not desirable, and the duration of control will largely depend on the future of Coyotes on the Gaspé peninsula. This relatively new predator species has successfully colonized the region although its fecundity was low at the time of this study (M.-L. Poulle, M. Crête and J. Huot, unpublished report). Coyotes seem to depend largely on White-tailed Deer in winter (Poulle et al. 1993), but this cervid species crashed in the region after the mid-1980s due to a series of harsh winters (Breton 1992). Harvest by hunting of adult males declined from 1094 in 1986 to 143 in 1991, which parallels variations in the size of deer wintering areas; hunting was closed in 1992. Reduced population of both deer and coyotes are possible in the future, which could reduce predation of Coyotes on Caribou. The abundance of alternate prey, e.g. Snowshoe Hare (*Lepus americanus*) in Newfoundland and Moose in British Columbia, have also influenced levels of predation on Caribou (Bergerud 1983; Bergerud and Elliot 1986).

The studied Caribou population illustrates well the difficulty of conserving an isolated and small population of large mammals. The arrival of Coyotes in

the region and the resultant decline in Caribou recruitment were unforeseeable. Our study demonstrates that such populations must be monitored closely even if they are protected by a park, because population dynamics can change rapidly. This Caribou population, for which quantitative information has been available since 1953 (Moisan 1957), may provide some answers to many questions that remain concerning the persistence of small isolated populations in fragmented habitat (Shafer 1990).

The Gaspésie Park Caribou herd has a good chance of persisting if calf survival remains at ≈ 0.50 and if the annual survival rate of adults remains as high as it was during telemetry monitoring; i.e., ≥ 0.90. High adult survival is the key to maintaining the herd. With survival > 0.90 after the first six months of life, an autumn ratio of 30-35 calves: 100 females would ensure replacement of adult deaths and would provide for a slight population increase. However, the carrying capacity of the park for Caribou is limited and density-dependent mechanisms are expected to become detectable if the population increases. The future of the Gaspésie Park Caribou herd, because of the size of the canid species involved, is more hopeful than that of some remnant Caribou herds at the southern extreme of the species range in western North America where the mortality rate of adults is high due to Gray Wolf predation (Seip 1992).

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The Spread and Current Distribution of European Frogbit, *Hydrocharis morsus-ranae* L., in North America

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Catling, Paul M. and Z. Sue Porebski. 1995. The spread and current distribution of European Frogbit, *Hydrocharis morsus-ranae* L., in North America. Canadian Field-Naturalist 109(2): 236–241.

European Frogbit became established in the vicinity of Ottawa during the late 1930s and at Montreal during the early 1950s. By 1980, it had spread approximately 200 km northeast of Montreal along the St. Lawrence River and approximately 200 km southwest of Ottawa into the Bay of Quinte region in eastern Lake Ontario. It was frequent and often a marsh dominant throughout this area and at a disjunct site at Rondeau Park on Lake Erie. It appeared in the northwestern Lake Ontario marshes in 1982. Recently, its range has extended (1) to the Point Pelee and Long Point marshes on Lake Erie, (2) along the lower Trent-Severn waterway, (3) along the north, east, and south shores of Lake Ontario, (4) inland north of eastern Lake Ontario, and (5) in the Lake Champlain area. European Frogbit has thus spread to 644 km from the lower Ottawa valley region of origin. The maximum overall rates of spread since 1939 to Point Pelee, Rondeau Park, and Bay of Quinte are 11.9, 15.6, and 5.5 km/year respectively. It appears that the mostly acidic and/or nutrient-poor waters of the Canadian Shield and the northern Appalachian region have acted as a partial barrier to its spread to the north, east and west, but it has recently been found in isolated lakes at the top of watersheds in the granitic barrens north of eastern Lake Ontario. Based on (1) the rate of spread since 1976, (2) evident climatic tolerance of the introduced genotypes, and (3) distribution of optimal habitats, it is anticipated that European Frogbit will spread throughout much of southern and western New York State, throughout southwestern Ontario, and further west into southern Great Lakes basin of Illinois, Indiana, Michigan, Ohio and Wisconsin over the next 10 years. It is anticipated that within 20 years it could become prevalent in the northern midwest and prairie regions of North America.

Key Words: European Frogbit, *Hydrocharis morsus-ranae*, alien, aquatic, weed, distribution, invasion, Ontario.

European Frogbit (*Hydrocharis morsus-ranae* L., Figure 1) is a common plant in temperate regions of Eurasia (Cook and Luond 1982). Its introduction and initial dramatic spread in North America are well documented (e.g., Minshall 1940; Dore 1968a,b; Catling and Dore 1982; Cook and Luond 1982; Cook 1985; Lumsden and McLachlin 1987; White et al. 1993) and some recent floristic manuals have alluded to its presence (Scoggan 1978; Gleason and Cronquist 1991). The most recently published dot map is that of Fleurbec (1987).

In Ontario, Quebec and northern New York, European Frogbit has become a nuisance in some areas as a result of the development of large free-floating mats of intertwining plants which inhibit recreational activities and limit water traffic. In addition, dense floating mats of Frogbit reduce growth of native submersed aquatic plants that appear to support a greater diversity of native aquatic organisms (Catling et al. 1988). It is one of five invasive alien plants that is reported to have had a major impact on natural ecosystems in Canada (Mosquin and Whiting 1992). Since it forms turions, has a free-floating phase and forms dense intertwining floating mats, it has the potential to become a major weed of irrigation systems requiring management that could have substantial environmental impact. The number of requests recieved by Agriculture Canada for current information on the status of the plant is rapidly increasing, and will likely continue to increase as the geographic distribution is further extended. If and when European Frogbit reaches the prairie irrigation districts of Canada and the prairie pothole waterfowl breeding grounds of Minnesota, the Dakotas and the southern prairie provinces, it will become a major concern on a continental scale.

Some of the studies noted above provided detailed information on both presence and absence at a particular time within certain geographic regions (e.g., Dore 1968b; Lumsden and McLachlin 1987). In addition, the region of Canada within which European Frogbit is established is one of the best known botanically in all of Canada and one recently under intensive biological study with respect to land-use planning. Thus an accurate assessment of spread and changing abundance is possible. The purpose of the present work is to review the spread of this plant in North America, present an update on its distribution and to outline predictions of future occurrence in North America based on the recently observed trends.

Methods

Literature concerning the occurrence of European Frogbit in North America was summarized and herbarium specimens were confirmed so as to pro-

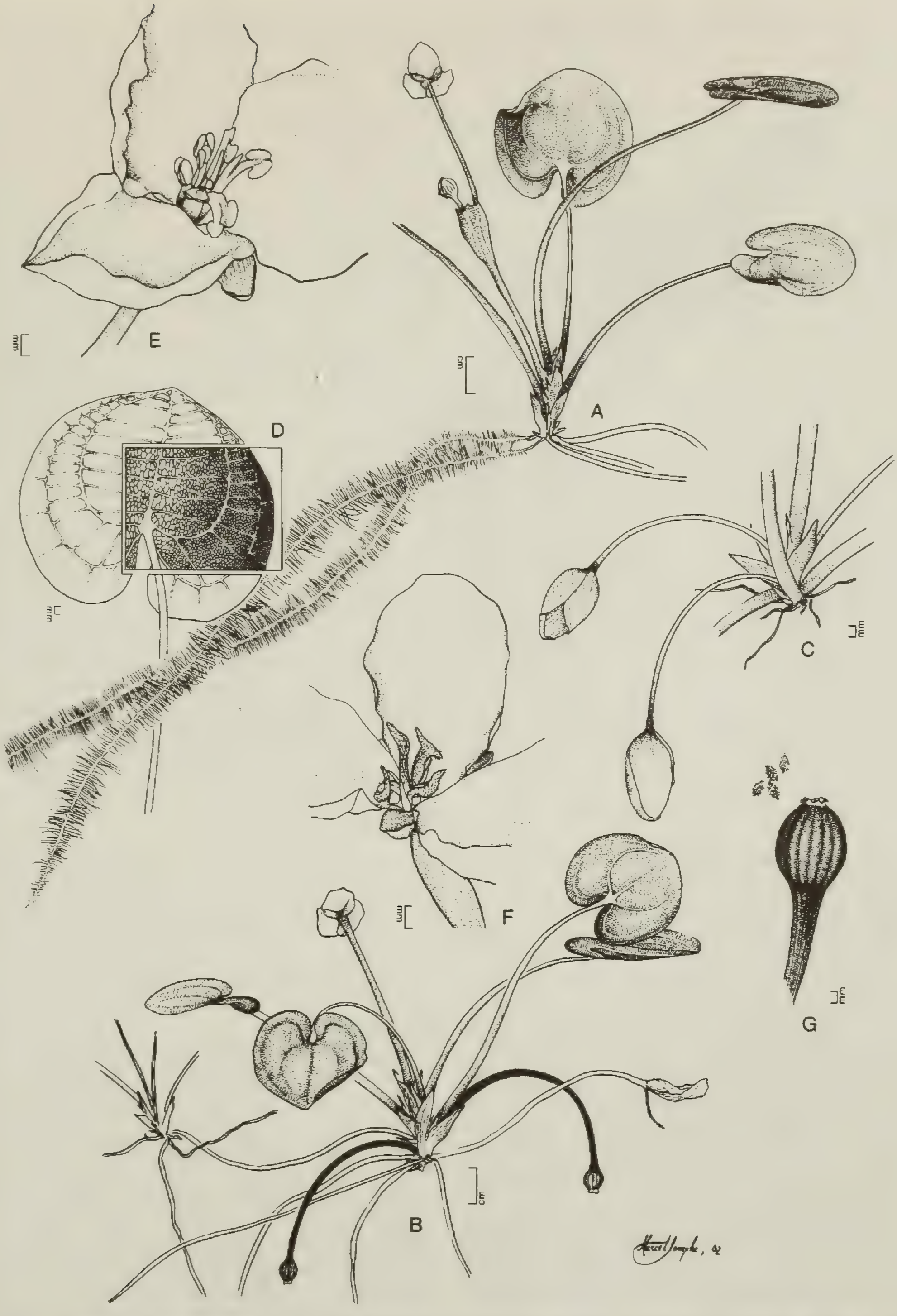

FIGURE 1. *Hydrocharis morsus-ranae* L. a, habit showing two staminate flowers arising from the same spathe; b, habit showing plantlets, pistillate flower and recurved fruiting peduncle; c, portion of plant base with two overwintering turions; d, detail of undersurface of leaf; e, staminate flower; f, pistillate flower; g, fruit and seeds. Drawn by Marcel Jomphe from material collected at Constance Creek, Ontario.

vide a basis for distribution maps. Specimen vouchers were obtained for significant range extensions beyond those in the most recently produced maps (e.g., Fleurbec 1987; Lumsden and McLachlin 1987; White et al. 1993). Quikmap version 2.51 (ESL Environmental Sciences Ltd., Sidney, British Columbia) and dBase IV (Ashton-Tate Corp., Torrance, California) files were used to prepare distribution maps for 10-12 year time intervals resulting in the production of a contour map illustrating the spread from 1942 to present, as well as a current (1994) dot map. Herbaria containing specimens that were examined included CAN, DAO, GH, MICH, MT, NYS, OAC, OS, QFA, QK, SFS and TRT (Holmgren et al. 1990).

Results and Discussion

Early establishment

In 1932, European Frogbit was introduced into a trench, which connected a pond to Dows Lake, in the arboretum of the Central Experimental Farm in Ottawa. It is probable that plants from this stock escaped into the Rideau Canal, where it was observed in 1939 and 1944 (Minshall 1940), and from there into the Rideau and Ottawa Rivers, and later over a broad geographical area (see below). However, in 1944 it was also established in Brown's Inlet, an artificial pond adjacent to the Canal (Dore 1968b). This pond and another nearby pond have had well established populations of alien aquatics for many years including species such as Flowering-rush (*Butomus umbellatus* L.), European Frogbit, Purple Loosestrife (*Lythrum salicaria* L.), Water-lilies (*Nymphaea* spp.), and Yellow Floating Heart (*Nymphoides peltata* (Gmel.) Rendle). Flowering-rush was established there in 1906. Thus, the possibility that European Frogbit was introduced at and escaped from Brown's Inlet cannot be ruled out.

One other aspect of early introduction that has to be considered is that the early records from Montreal in 1952 (Dore 1954, 1968b), and the absence of any reports for the area between Ottawa and Montreal at the time, suggest that there may have been a separate introduction in the Montreal area (Raymond and Kucyniak 1947; Catling and Dore 1982). Interestingly, the Flowering-rush, also appears to have been introduced into North America at Montreal, where the first specimens were collected in 1905 (Core 1941).

The reason for possible deliberate introduction is not clear. With its floating habit and rapid vegetative reproduction, it has interest as a plant with unusual morphology. In addition, it has been extensively used in plant physiology research and teaching because of the general ease of culture and unusually large root hairs within which cytoplasmic streaming is readily observed (Minshall 1940).

Review of spread until 1982

European Frogbit was observed in the Rideau Canal system in 1939 (Minshall 1940; Dore 1968a, b). By 1944, it was well established in the Dows Lake - Rideau Canal area of Ottawa and by 1953 large masses of free-floating plants were observed in the Rideau Canal and the Ottawa River near Cumberland, Ontario, 21 km east of Ottawa (Dore 1954). In 1952, it was found on Rivière des Mille-Îles near the confluence of the Ottawa and St. Lawrence rivers near Montreal (Dore 1968b; Catling and Dore 1982). By 1956, it was well established in the Ottawa-Cumberland and Montreal areas (Dore 1968b).

In 1967, European Frogbit was common along the Ottawa River to Montreal and north along the St. Lawrence River to Lake St. Peter (Louis-Marie 1958a,b, 1960, 1961, 1962; Dore 1968a,b). Distribution in Quebec was documented by Joyal (1970). Not only was Frogbit drifting down the major rivers but it was also discovered upstream in the Ottawa, St. Lawrence and Rideau rivers. It was first recorded in the Bay of Quinte, northeastern Lake Ontario, in 1972 (Catling and Dore 1982). The first report from New York State was from the St. Lawrence River in 1974 (Catling and Dore 1982; Roberts et al. 1981). It was first recorded on Lake Erie at Rondeau in 1976 (Catling and Dore 1982), at which time it was rare, but it became abundant and dominant in the marshes there within five years. By 1979, European Frogbit had extended up the Ottawa River to Westmeath and Fort Coulonge, and it had extended to Quebec City on the St. Lawrence River (Reddoch 1976; Gauthier 1980; Catling and Dore 1982). By the later 1970's, it had been found at many localities in New York State (Roberts et al. 1981), some well to the south of the St. Lawrence River. Apart from the isolated occurrence at Rondeau, the total extent of continuous North American distribution by 1982 (Figure 2) was a stretch of major waterways 530 km in length.

Recent spread

Frogbit was first discovered in the lower Trent-Severn waterway system at Wilson Island in 1989 (*Catling s.n.*, DAO) and well within the granitic rock barrens of eastern Ontario north of Tamworth in 1994 (*Brownell & Catling 20603*, DAO). It was first noticed on the east shore of Lake Ontario in 1987 (*Catling 8013* DAO), and along the northwest shore in 1982 and was subsequently found to be abundant in the northwestern Lake Ontario marshes (Lumsden and McLachlin 1987). Also, in 1987 Frogbit was shown to occur in the Lake Champlain region (Fleurbec 1987). The first record from the south shore of Lake Ontario was from near Sodus Bay in 1993 (*Catling 14030*, DAO). The first observations in the Lake Erie region outside Rondeau were in

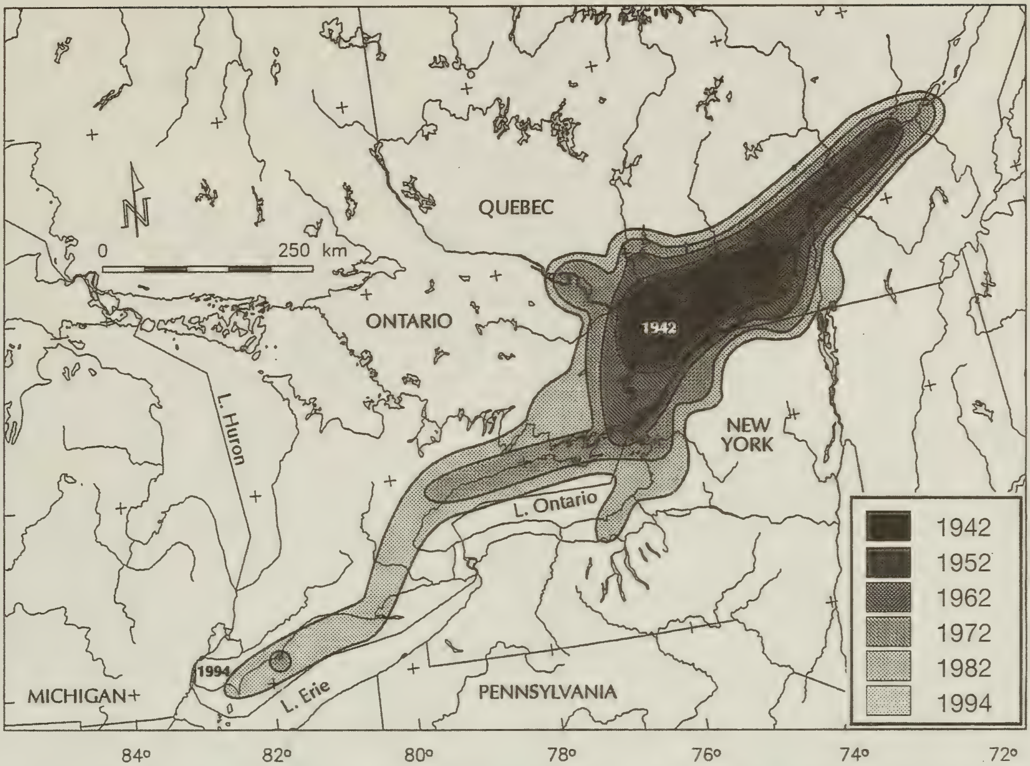

FIGURE 2. Contour map illustrating the changing distribution of *Hydrocharis morsus-ranae* in North America over 10-12 year intervals beginning in 1942 (1952, 62, 72, 82, 94), 10 years after introduction at Ottawa (based on examination of specimens at CAN, DAO, MT, NYS, OAC, QFA, SFS and TRT).

1988 at Point Pelee (*Oldham 8665* DAO, *Reznicek 8397* DAO, MICH) and at Long Point Crown Marsh in 1993 (*Sutherland 9591*, DAO). The area of distribution to 1994 extended from Point Pelee on Lake Erie in southwestern Ontario to Québec City, up the Ottawa River to Fort Coulonge, south along the Richelieu River system to the north end of Lake Champlain (Figure 3). It is now common through much of this region in smaller streams, lakes, and beaver ponds (personal observation).

Rate of spread

European Frogbit has spread up to approximately 644 km from the lower Ottawa valley region of origin to Point Pelee National Park in western Lake Erie (Figures 2, 3). The maximum overall rates of spread since 1939 to Point Pelee, Rondeau Park, and Bay of Quinte, in straight lines from the Ottawa origin, are 11.9, 15.6 and 5.5 km/year respectively. Within five years of initial establishment, it can become a locally dominant wetland plant.

While whole plants and turions may be dispersed by water, by birds and by boats, its rapid colonization of isolated marshes and beaver ponds suggests that dispersal of seeds by birds is important (Catling and Dore 1982). This latter means of dispersal seems most likely to account for some of the long distance dispersal events such as eastern Ontario to western Lake Erie prior to 1976.

Probable patterns of future spread based on recent trends

Although Cook and Luond (1982) indicate that it favours calcium-poor water, often occurring on peaty soil types, European Frogbit has not been found in oligotrophic conditions in North America and should probably be considered characteristic of mesotrophic waters. Many eastern Ontario populations are in nutrient-rich, or at least calcium-rich waters with pH 6.5 - 7.8 (Catling and Dore 1982). In Ontario, European Frogbit is most often associated with *Butomus umbellatus*, *Lemna minor*, *Lythrum salicaria*, *Myriophyllum sibiricum*, *Myriophyllum spicatum*, *Potamogeton pusillus* var. *tenuissimus*, *Potamogeton vaseyi*, *Spirodela polyrhiza*, *Typha latifolia* and *Utricularia vulgaris* (Catling et al. 1988; Lumsden and McLachlin 1988; Spicer and Catling 1990). Waters and aquatic vegetation of this type are

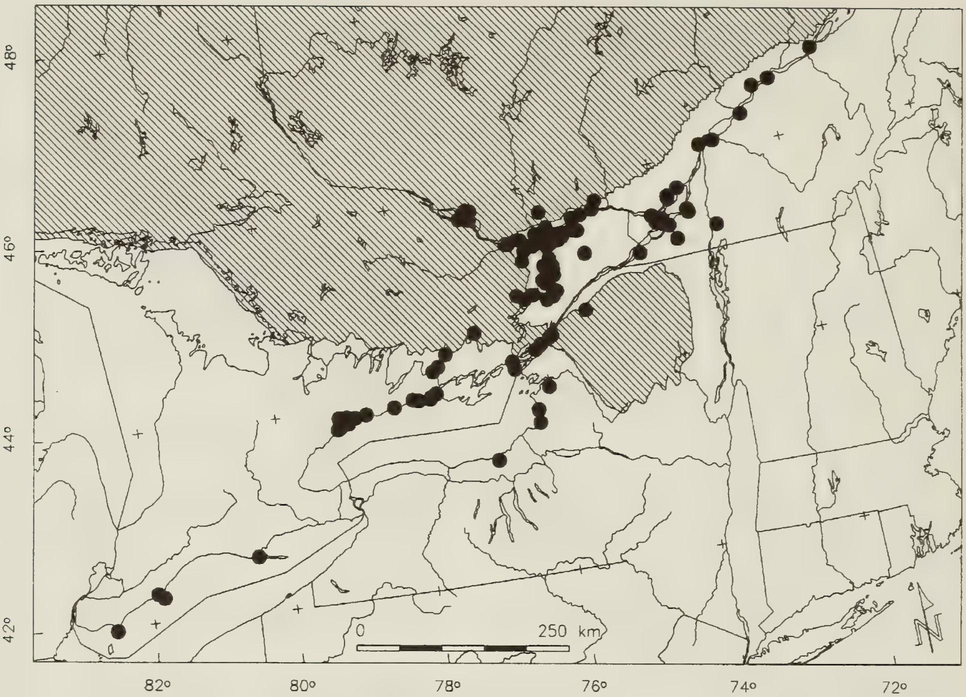

FIGURE 3. Distribution of *Hydrocharis morsus-ranae* in North America up to 1994 based on examination of specimens at CAN, DAO, MT, NYS, OAC, QFA, SFS and TRT. The shaded area represents the Canadian Shield region of largely granitic upland.

absent from much of the Canadian Shield region to the north, east and west of the current distribution and are also absent in the Appalachian uplands to the east. The apparent obstacle presented by relative scarcity of habitat in much of the Canadian Shield and Appalachian upland is supported by the limited spread into this region (Figure 3), and resultant confinement to the northeast - southwest axis of the lower Great Lakes - St. Lawrence system. However, Frogbit has recently been found at the top of a watershed in the granitic barrens north of Tamworth in eastern Ontario (*Brownell & Catling 20603*, DAO), so that the extent to which the Canadian Shield will be a complete barrier is uncertain.

Since it occurs from Point Pelee to Quebec City, the genotype(s) of European Frogbit established in North America appear to have a broad climatic tolerance. It has now colonized portions of two major ecozones of Canada and four ecoregions (*cf.* Canada Terrestrial Ecoregions, National Atlas Information Service 1993: Wiken 1986).

Evidently, appropriate habitat for European Frogbit occurs throughout much of southern New York, all of southwestern Ontario and generally throughout much of the southern portion of the Great Lakes basin including portions of the states of Illinois, Indiana, Michigan, Ohio and Wisconsin. It is anticipated that European Frogbit will spread throughout much of this area over the next 10 years based on its recent rate of spread in this direction (Figure 2), distribution of appropriate habitat and evident climatic tolerance of the introduced genotype. It is quite possible that within 20 years it will have become prevalent in the midwestern and the prairie regions of North America, following the patterns of spread of other European invasive aquatics such as Flowering-rush (Boutwell 1990; Core 1941; White et al. 1992) and Purple Loosestrife (Thompson et al. 1987) which have similar Eurasian distributions, similar early patterns of North American colonization and with which European Frogbit often occurs in its present North American range. A significant spread southward in the Lake Champlain area may also be anticipated as the first record in the New England states. The recent colonization of the lower Trent-Severn waterway is likely to result in a rapid spread throughout this canal system to the Georgian Bay region of Ontario. A limited spread eastward along the St. Lawrence may also be anticipated since sufficient freshwater habitats exist for other introduced aquatics such as European Water-horehound

(*Lycopus europaeus* L.) and Flowering-rush to have colonized this region.

In general, European Frogbit has been rare and present as a few isolated patches when first discovered in an area, but has become a dominant or co-dominant of local aquatic ecosystems within five years.

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Vascular Flora of Sand Barrens in the Middle Ottawa Valley

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In order to provide information relevant to the protection of native vegetation of dry sandy openings in the middle Ottawa valley, species lists were produced for seven sites and descriptions based on quadrats were obtained for four of these. The dominant species in terms of cover at four sites were *Carex lucorum*, *Comptonia peregrina*, *Danthonia spicata*, *Prunus susquehanae* and *Vaccinium angustifolium*. Other frequent and prominent species present at most or all of the seven sites included *Apocynum androsaemifolium*, *Arctostaphylos uva-ursi*, *Aster ciliolatus*, *Carex foenea*, *Carex rugosperma*, *Carex tonsa*, *Fragaria virginiana*, *Oryzopsis asperifolia*, *Oryzopsis pungens*, *Panicum columbianum*, *Panicum depauperatum*, *Panicum linearifolium*, *Panicum implicatum*, *Pinus banksiana*, *Pinus strobus*, *Poa pratensis*, *Polygonella articulata*, *Populus tremuloides*, *Prunus virginiana*, *Prunus pensylvanica*, *Pteridium aquilinum*, *Solidago hispida*, and *Viola adunca*. There was variation between sites in both species composition and cover as well as overall richness: the number of native species ranging from 34 to 63. Twelve regionally rare and four provincially rare species were recorded in the seven sites. Differences in dominance and composition of sand barren vegetation in eastern Canada are discussed and both east-west and north-south trends of variation are noted. The sand barrens are apparently long persisting, distinctive natural habitats dominated by native species, and they have been under-emphasized in planning for representative habitat protection.

Key Words: Sand barrens, vascular flora, rare plants, Ottawa River, Ontario, Canada.

Vegetation of naturally occurring dry openings over rock such as limestone barrens or alvars (e.g., Catling 1995) and granite barrens (e.g., Brownell, 1994*), or on deeper soils including prairies and sand barrens (e.g., Catling and Catling 1993), is restricted in Ontario and thus significant with regard to the protection of representative examples. The presence of dry heathlands and grasslands or Jack Pine "barrens" on sandy plains and dunes in the middle Ottawa valley has been known for a long period, but the potential importance of these areas as representatives of a distinctive natural ecosystem appears to have been under-emphasized. These vegetation types are frequently referred to as "sand barrens" (e.g., Hall and Aalders 1968), where "barrens" refers to a lack of trees and patches of bare sand rather than the absence of any vegetation. Indeed, there is little information on the floristic composition of Ontario sand barrens, which are lumped with acidic rock barrens in the only general description available (Kavanagh and McKay-Kuja 1992*) which is not quantitative.

The lack of attention to sand barrens in the middle Ottawa valley may be a result of the fact that they are regarded as transitional or successional and are the result of fire or disturbance. A degree of fire dependence, however, does not seem to have discouraged interest in protection of this kind of vegetation elsewhere. In northern Michigan for example, Jack Pine barren vegetation similar to that of the middle Ottawa valley is managed and recognized as the significant habitat of the endangered Kirtland's Warbler (*Dendroica kirtlandii*) (Byelich et al. 1986*).

Regardless of the possible explanation, Brunton (1991*) found that sand barrens were not represented within the system of designated significant sites in the Ontario portion of the middle Ottawa valley so he proposed reserve areas in the Lake Traverse dunes and at Driftwood Provincial Park to fill the gap. While this was a significant step forward, the selection was not based on a clear definition of the vegetation, and an extensive survey of possible sites was beyond the scope of his report.

Here, we provide a clearer definition of sand barren vegetation in the middle Ottawa valley through a quantitative floristic description and a brief consideration of aspects such as origin, significant flora and regional variation. This information is relevant to future protection of these sites.

Methods

The study area consists of seven sites in the middle Ottawa valley (Table 1). Aerial photographs and topographical maps were used to determine the most probable locations of natural dry, sandy openings. Only sites not disturbed by agricultural practices or excess vehicle traffic were selected. Sites with scattered trees and groves and open woodlands, suggesting long established natural openings, were favoured. Areas surveyed varied from approximately 2-10 hectares in extent.

*See Documents Cited section preceeding Literature Cited.

TABLE 1. Names and locations of sand barren study sites in the Ottawa valley.

Site Name	Latitude	Longitude	Map	UTM
Alice	45°44′00	77°19′00	31\F11	198682
Bonnechere	45°39′00	77°36′00	31\F12	982597
Mattawa	45°57′00	77°19′00	31\F14	200925
Petawawa	45°55′00	77°34′00	31\F14	014880
Lake Traverse	45°57′00	78°03′00	31\E16	285925
Wilbert	45°53′00	77°18′00	31\F14	224849
Blackbay	45°51′60	77°19′00	31\F14	219814

All sites were visited on at least two occasions in 1993, with one visit in early summer and another in autumn. Species lists were made at each of the seven sites (Table 2). An abundance value ranging from 0 - 3 was assigned to each species (1 = rare, 2 = moderately common or frequent, 3 = dominant over at least 20% of area surveyed). Voucher specimens collected at various sites were deposited in the vascular plant herbarium at Agriculture Canada in Ottawa (DAO) and voucher specimens collected by others are deposited at the Algonquin Park Museum (APM). Regional rarity of plant species was determined using Moore's middle Ottawa valley checklist (1978) and the Algonquin Park checklist (Brunton and Crins 1992). Provincial rarity was determined using the Atlas of the Rare Vascular Plants of Ontario (Argus et al. 1982-1987) and the more recent Natural Heritage list (Oldham 1994).

Vascular plants were recorded in each of 25 quadrats spaced at 3 m intervals along transects selected to represent the topographic variation at each of four sites (Tables 3 and 4). Mean percent frequency and mean percent cover were determined. Cover of each species in each quadrat was evaluated subjectively as one half of the surface area of each species within the quadrat, by visualizing the area of ground surface that would be covered by each species if its parts were laid flat and joined without overlapping. Percent frequency was obtained by dividing the number of quadrats in which a species was present by 25. Frequently used common names (e.g., Fernald 1950) are provided in Table 2.

Results and Discussion

Limitations of the vegetation description

The evaluation of floristic abundance was complicated by the fact that some plants could not be positively identified. One of the problems involved separating *Carex pensylvanica* Lam. and *C. lucorum* Willd., but extensive collections in the middle Ottawa valley area suggest that plants on the acidic sand plains are invariably referable to *Carex lucorum* (W. Crins, personal communication).

Another identification problem involved species of *Amelanchier*. Field identifications often had to be revised and even some flowering or fruiting specimens could not be identified with certainty, presumably due to hybridization (McKay 1973*). Most of the plants present were referable to *Amelanchier spicata* (Lam.) K. Koch (including var. *spicata* and var. *stolonifera* (Wieg.) Cinq-Mars) and *Amelanchier alnifolia* (Nutt.) Nutt. var. *compacta*, but *Amelanchier sanguinea* (Pursh) DC. var. *sanguinea* and *A. alnifolia* var. *alnifolia* were also quite frequent. Material referable to both *Panicum depauperatum* Muhlenb. and *P. linearifolium* Scribner was present at most sites but due to problems in separating these freely hybridizing species (S. J. Darbyshire, personal communication) they were recorded collectively as *Panicum* cf. *linearifolium*. Finally, the species and varieties of *Antennaria* were not determined during field recording, although some material collected was determined as *Antennaria howellii* E. Greene ssp. *petaloidea* Fern.

Dominant plants and site variation

The dominant species in terms of cover at four sites were the shrubs *Comptonia peregrina* L. Coulter, *Prunus susquehanae* Willd. and *Vaccinium angustifolium* Aiton and the graminoid herbs *Carex lucorum*, and *Danthonia spicata* L. (Tables 2, 4). Other frequent and prominent species present at most or all of the seven sites included *Apocynum androsaemifolium* L., *Arctostaphylos uva-ursi* (L.) Sprengel, *Aster ciliolatus* Lindley, *Carex foenea* Willd., *Carex rugosperma* Mackenzie, *Carex tonsa* (Fern.) Bickn., *Fragaria virginiana* Duchesne, *Oryzopsis asperifolia* Michaux, *Oryzopsis pungens* (Torrey ex Sprengel) A. Hitchc., *Panicum columbianum* Scribner, *Panicum depauperatum*, *Panicum linearifolium*, *Panicum implicatum* Scribner, *Pinus banksiana* Lambert, *Pinus strobus* L., *Poa pratensis* L., *Polygonella articulata* (L.) Meissner, *Populus tremuloides* Michaux, *Prunus virginiana* L., *Prunus pensylvanica* L. f., *Pteridium aquilinum* (L.) Kuhn, *Solidago hispida* Muhl. and *Viola adunca* Smith (Tables 2, 3). The dominant tree species scattered within and surrounding all seven

TABLE 2. Species presence, abundance and status at seven sand barren sites in the middle Ottawa valley. 1 = rare, 2 = moderately common or frequent, 3 = dominant over at least 20% of area surveyed. + = regionally rare or not listed by Moore (1978). * = regionally rare based on rarity or absence in Brunton and Crins (1992). P = provincially rare based on Argus et al. (1982-1987) and Oldham (1994). I = introduced. Authorities for scientific names may be obtained from Brunton and Crins (1992) or Morton and Venn (1990).

			Site Name						
Status	Species	Common Name	Wilbert	Bonne	Alice	Petawa	Mattaw	Black	L.Trav
	Achillea millefolium	Yarrow	-	-	-	-	-	-	1
	Agrostis scabra	Hair Grass	2	-	-	2	1	3	-
	Agrostis stolonifera	Creeping Bent Grass	-	-	-	1	3	-	-
	Ambrosia artemisiifolia	Bitter-weed	2	-	-	-	-	-	-
*	*Amelanchier alnifolia sensu lato*[1]	Saskatoon Serviceberry	2	3	3	3	2	1	2
	Amelanchier arborea ssp. *laevis*	Downy Serviceberry	-	2	-	-	-	-	-
	Amelanchier sanguinea sensu lato	Round-leaf Serviceberry	1	3	-	3	3	1	2
	Amelanchier spicata var. *stolonifera*	Serviceberry	1	2	-	2	2	-	1
	Anaphalis margaritacea	Pearly Everlasting	-	-	-	1	-	-	-
*	*Anemone canadensis*	Canadian Anemone	-	-	-	1	-	-	-
*	*Anenome cylindrica*	Thimbleweed	-	-	-	1	1	-	-
*	*Antennaria howelii* ssp. *petaloidea*[2]	Everlasting	1	1	-	1	-	1	
	Apocynum androsaemifolium	Bitter Dogbane	2	2	1	3	3	1	1
	Arabis divaricarpa	Rock Cress	1	-	-	1	1	-	-
	Aralia hispida	Bristly Sarsaparilla	-	-	-	1	1	-	-
	Arctostaphylos uva-ursi	Bearberry	1	3	-	1	3	1	3
	Aronia prunifolia	Chokeberry	-	3	-	2	-	-	-
	Asclepias syriaca	Common Milkweed	1	-	-	2	-	1	-
	Aster ciliolatus	Lindley's Aster	1	1	1	1	2	2	-
	Betula papyrifera	Paper Birch	1	2	-	-	-	-	-
*+P	*Bulbostylis capillaris*	Bulbostylis	1	-	-	-	-	-	-
	Calystegia spithamaea ssp. *spithamaea*	Low Bindweed	-	2	-	1	2	-	-
+	*Campanula rotundifolia*	Round-leaved Bluebell	-	1	-	-	-	1	-
	Carex houghtoniana	Houghton's Sedge	-	-	-	2	2	3	-
*	*Carex argyrantha*	Silvery-flowered Sedge	1	-	-	-	-	-	-
*+	*Carex cumulata*	Sedge	-	-	-	-	-	1	-
	Carex debilis	Sedge	-	1	1	-	-	-	-
*	*Carex foenea*	Hay Sedge	2	3	1	3	2	1	2
*	*Carex lucorum*	Sedge	2	3	3	2	3	1	2
*	*Carex* cf. *merritt-fernaldii*	Fernald's Sedge	-	-	-	1	-	-	-
	Carex rugosperma	Sedge	1	1	3	2	1	-	2
*	*Carex tonsa*	Shaved Sedge	1	2	1	1	2	2	-
	Ceanothus herbaceus	Red Root	-	2	-	1	2	-	-
I*	*Chenopodium glaucum*	Oak-leaf Goosefoot	-	-	-	1	1	-	-
	Comandra richardsiana	Bastard-toadflax	-	1	2	-	1	-	-
	Comptonia peregrina	Sweetfern	3	3	3	2	3	3	3
I	*Conyza canadensis*	Bitterweed	2	-	-	-	-	-	-
	Corylus cornuta	Beaked Hazel	-	1	-	1	-	-	-
*+	*Cycloloma atriplicifolium*	Tumbleweed	-	-	-	1	-	-	-
*P	*Cyperus houghtonii*	Houghton's Umbrella-sedge	1	-	-	-	1	-	-
	Cypripedium acaule	Moccasin-flower	-	2	1	-	-	-	-
	Danthonia spicata	Poverty Grass	2	3	3	3	3	3	2
	Diervilla lonicera	Bush-honeysuckle	1	-	-	-	-	-	-
*	*Elymus canadensis*	Canadian Wild-rye	-	-	-	1	1	-	-
I	*Elymus repens*	Couch-grass	2	-	-	1	3	3	-
	Elymus trachycaulus	Bearded Couch-grass	-	1	-	-	-	-	1
	Epigaea repens	Trailing Arbutus	1	-	-	-	-	-	-
	Epilobium angustifolium	Fireweed	1	2	-	2	-	-	1
*	*Equisetum hyemale*	Evergreen Scouring Rush	-	-	-	3	-	2	-
I	*Euphorbia sp.*	Ridge-seed Spurge	-	-	-	-	-	2	-
	Euthamia graminifolia	Grass-leaved Goldenrod	1	-	-	1	1	-	-
I*	*Festuca trachyphylla*	Fescue	-	-	-	-	-	1	-
	Fragaria virginiana	Wild Strawberry	3	2	1	1	1	1	-
*	*Gnaphalium obtusifolium*	Catfoot	-	-	-	2	1	-	-

Continued

TABLE 2. *Continued.*

Status	Species	Common Name	Site Name Wilbert	Bonne	Alice	Petawa	Mattaw	Black	L.Trav
*+	*Helianthemum canadense*	Canadian Frostweed	-	1	-	-	-	-	-
I	*Hieracium aurantiacum*	Devil's-paintbrush	-	-	-	-	-	-	1
	Hieracium canadense	Canadian Hawkweed	1	-	-	-	2	-	-
I	*Hieracium piloselloides*	King Devil	3	-	-	-	-	2	-
*+P	*Juncus greenei*	Greene's Rush	1	-	-	-	-	-	-
	Kalmia angustifolia	Sheep-laurel	1	1	1	1	1	-	-
	Lechea intermedia	Pinweed	-	-	-	-	2	-	-
	Lepidium densiflorum	Green-flowered Pepper-weed	-	-	-	1	1	-	-
	Lycopodium cf. *tristachyum*	Ground-cedar	-	-	-	-	1	-	-
*	*Lysimachia quadrifolia*	Prairie Loosestrife	-	-	-	3	2	-	-
*	*Muhlenbergia glomerata*	Clustered Muhly	2	1	-	-	-	-	2
I	*Mollugo verticillata*	Carpetweed	-	-	-	1	-	-	-
	Oryzopsis asperifolia	Harsh-leaved Mountain-rice	2	2	1	2	1	-	3
+	*Oryzopsis canadensis*	Canadian Mountain-rice	-	1	1	-	-	-	-
+	*Oryzopsis pungens*	Pointed Mountain-rice	2	2	2	2	2	-	2
*	*Panicum columbianum*	Panic-grass	2	2	2	1	2	-	-
	Panicum implicatum	Panic-grass	2	1	-	-	3	2	2
	Panicum linearifolium[4]	Panic-grass	2	2	1	2	2	1	1
	Picea glauca	White Spruce	-	1	1	-	-	-	2
	Pinus banksiana	Jack Pine	3	3	3	3	3	2	3
	Pinus resinosa	Red Pine	3	-	-	2	1	-	-
	Pinus strobus	Eastern White Pine	1	2	2	-	-	1	2
I+	*Pinus sylvestris*	Scot's Pine	-	-	-	-	-	1	-
	Poa pratensis	Kentucky Bluegrass	2	1	1	3	2	2	2
*	*Polygala polygama*	Milkweed	-	1	-	-	-	-	-
P	*Polygonella articulata*	Jointweed	2	2	2	3	2	3	3
	Polygonum convolvolus	Black Bindweed	-	-	-	1	1	-	1
	Populus balsamifera	Balsam Poplar	-	-	-	-	-	1	1
	Populus tremuloides	Quaking Aspen	3	2	-	1	1	1	-
I	*Potentilla argentea*	Hoary Cinquefoil	3	1	-	1	1	-	2
	Potentilla arguta	Tall Cinquefoil	-	1	1	1	1	-	-
*	*Potentilla canadensis*	Canada Cinquefoil	-	1	1	-	-	-	1
I	*Potentilla* cf. *inclinata*	Cinquefoil	-	-	-	-	2	-	-
I	*Potentilla norvegica*	Rough Cinquefoil	-	-	-	1	2	-	-
I	*Potentilla recta*	Rough-fruited Cinquefoil	-	-	-	2	-	-	-
	Potentilla simplex	Old Field Cinquefoil	-	-	1	-	2	-	-
	Potentilla tridentata	Three-toothed Cinquefoil	-	1	-	-	-	-	-
	Prunus pensylvanica	Bird Cherry	2	2	1	-	2	-	-
	Prunus susquehanae	Appalachian Dwarf Cherry	2	3	-	2	3	1	2
	Prunus virginiana	Bird Cherry	-	-	3	2	2	1	2
	Pteridium aquilinum	Bracken Fern	2	3	2	1	2	-	3
	Quercus borealis	Red Oak	1	1	-	-	-	-	-
*	*Quercus macrocarpa*	Bur Oak	1	-	-	-	-	-	-
*+	*Rhus aromatica*	Fragrant Sumac	1	-	-	-	-	-	-
	Rhus radicans	Poison Ivy	-	-	-	2	1	-	-
	Rosa blanda	Smooth Rose	-	-	2	2	1	-	-
*+	*Rosa carolina*	Carolinian Rose	-	-	-	1	-	-	-
	Rubus allegheniensis	Allegheny Blackberry	2	2	2	2	-	-	-
	Rubus pubescens	Dwarf Raspberry	-	-	-	2	1	-	-
	Rubus strigosus	American Red Raspberry	1	-	-	-	-	1	-
	Rudbeckia hirta	Black-eyed-Susan	-	-	-	2	1	-	-
I	*Rumex acetosella* ssp. *acetosella*	Sheep-sorrel	1	1	1	1	-	2	1
	Salix humilis	Gray Willow	1	-	2	-	-	1	-
	Schizachne purpurascens	False Melic	-	1	1	-	-	-	-
I*+	*Scleranthus annuus*	German Knotgrass	-	-	-	1	1	-	-
*	*Senecio pauperculus*	Balsam Ragwort	-	1	-	-	-	-	-
I	*Silene vulgaris*	Bladder-campion	2	-	-	-	-	2	-
	Smilacina racemosa	False Solomon's-seal	-	-	-	1	-	-	-

Continued

TABLE 2. *Concluded.*

			Site Name						
Status	Species	Common Name	Wilbert	Bonne	Alice	Petawa	Mattaw	Black	L.Trav
	Smilacina stellata	Starry False Solomon's-seal	-	-	-	3	-	-	-
	Solidago hispida	Hairy Goldenrod	2	1	-	2	2	2	1
	Solidago juncea	Early Goldenrod	1	-	-	-	-	-	-
	Solidago nemoralis	Gray (-stemmed) Goldenrod	2	1	1	-	-	1	1
	Solidago rugosa ssp. *rugosa*	Rough-stemmed Goldenrod	2	-	-	-	-	-	-
	Solidago squarrosa	Stout Goldenrod	2	-	-	-	-	-	-
I	*Sonchus sp.*	Sow-thistle	-	-	1	-	-	-	-
	Spiraea alba	Meadowsweet	1	2	1	-	1	1	2
*+	*Sporobolus cryptandrus*	Sand drop-seed	-	-	-	1	-	-	-
I*	*Tragopogon dubius*	Goat's-beard	-	1	-	2	1	1	-
I	*Trifolium aureum*	Hop-clover	-	1	-	-	-	-	-
	Vaccinium angustifolium	Low Sweet Blueberry	3	3	3	3	2	1	2
	Vaccinium myrtilloides	Velvet-leaf Blueberry	-	-	-	-	3	-	1
	Viburnum cassinoides	Wild-raisin	-	-	1	-	-	3	-
	Viola adunca	Hook-spur Violet	-	1	2	1	2	-	1
+	*Viola sororia*	Woolly Blue Violet	-	-	-	-	-	-	1
	Waldsteinia fragarioides	Barren Strawberry	3	-	-	-	-	-	1
	Number of Species								
	Native		55	57	39	63	58	34	37
	Introduced		5	4	2	4	7	8	3
	Total		60	61	41	67	65	42	40

[1] Material referable to both the var. *alnifolia* and var. *compacta* (McKay 1973) was collected at various sites but the varieties were not consistently distinguished in the field and abundance was determined only for the species level.

[2] Taxa of *Antennaria* were not distinguished in the field but several sheets collected were referable to this taxon, identified by Dr. R. J. Bayer.

[3] It was not possible to determine whether *Carex pennsylvanica* was present but *C. lucorum* was certainly predominant and even some confusing fruiting and vegetative specimens collected are best placed with the latter taxon (W. Crins, personal communication).

[4] Material referable to both *Panicum depauperatum* and *P. linearifolium* was present at most sites but the two species were treated collectively for assessment of abundance.

sand barren sites was *Pinus banksiana. Pinus resinosa* Aiton, *Pinus strobus* and *Populus tremuloides* were also present (Table 2).

Proximate sites tended to be most similar in floristic composition. The Petawawa and Mattawa plain sites were the most distinctive (Table 2). In addition to some unique species, these sites had relatively more graminoids at the expense of heath cover than other sites (Tables 2, 3, 4). There were substantial differences between sites in *Prunus susquehanae* and *Amelanchier* spp. cover (Table 4), but the greatest differences between sites were related to overall diversity which varied from 34 to 63 native species and 2-8 introduced species (Table 2). The relatively small number of introduced species and their relatively low cover is a result of the fact that sites were chosen partly on the basis of native species dominance and absence of anthropogenic disturbance.

Significant plants

The regionally rare taxa of the middle Ottawa valley sand barrens include 12 that are rare in the immediate area and 28 taxa that are rare in the adjacent Algonquin region (Table 2). The provincially rare species observed include *Bulbostylis capillaris* (L.) C. B. Clarke, *Cyperus houghtonii* Torrey, *Juncus greenei* Oakes & Tuckerman and *Polygonella articulata. Bulbostylis capillaris* and *Juncus greenei* may have been more common in the past when fires opened habitat on periodically moist sites. These species were largely confined to vehicle tracks and path edges in our study sites. Although not present on the sites we examined, other rare plant species reported from the sand barrens in this area including Beach-heath (*Hudsonia tomentosa* Nutt.) (Achray near Lake Traverse), Rigid Sunflower (*Helianthus rigidus*) (Cass.) Desf. ssp. *subrhomboideus* (Rydb.) Heiser (Petawawa Reserve) and Ground-fir (*Diphasiastrum* x *sabinifolium*) (Willdenow) Holub. (Petawawa).

Comparison with similar habitats elsewhere in eastern Canada

Although included with acidic rock barrens by Kavanagh and McKay-Kuja (1992*), sand barrens differ substantially. They lack some of the characteristic dominant species of rock barrens such as Common Hairgrass (*Deschampsia flexuosa* (L.)

TABLE 3. Mean % frequency of species occurring in more than 1 of 25 quadrats at four sites. Frequencies > 70% appear in boldface.

Species	Wilbe	Petawa	Bonnec	L. Traver
Agrostis scabra	60	0	0	0
Ambrosia artemisiifolia	16	4	4	0
Amelanchier spp.	**80**	32	**84**	**72**
Arctostaphylos uva-ursi	20	0	28	8
Bulbostylis capillaris	12	0	0	0
Carex lucorum	**92**	**92**	**100**	**92**
Carex tonsa	8	16	8	0
Comptonia peregrina	**100**	24	**96**	44
Cyperus houghtonii	12	0	0	0
Danthonia spicata	**96**	**92**	**84**	**72**
Fragaria virginiana	56	0	0	0
Hieracium piloselloides	56	0	0	0
Juncus greenei	20	0	0	0
Muhlenbergia glomerata	44	0	0	0
Oryzopsis pungens	**72**	8	56	20
Panicum columbianum	52	20	12	0
Panicum cf. *linearifolium*	44	4	4	4
Polygonella articulata	24	0	0	0
Potentilla argentea	60	4	0	0
Prunus susquehanae	**88**	52	**96**	68
Pteridium aquilinum	68	8	16	8
Rubus allegheniensis	64	0	0	0
Solidago hispida	48	44	12	0
Solidago nemoralis	28	0	12	0
Vaccinium angustifolium	**100**	64	**96**	**88**

Trin.), Spreading Juniper (*Juniperus communis* L.) and Early Saxifrage (*Saxifraga virginiensis* Michx.), as well as many bryophytes and lichens. Floristic similarities are nevertheless substantial.

The treeless and prairie-like central portion of the dune area at Constance Bay, on the Ottawa River was probably one of the best known sandy barrens in the Ottawa valley. Breitung (1957) describes this site as being dominated by *Vaccinium angustifolium*, *Comptonia peregrina*, New Jersey Tea (*Ceanothus americanus*), *Prunus susquehanae* and Black Huckleberry (*Gaylussacia baccata*). Very little of the "shrubland" vegetation remained in 1979 (White 1979; Boyd and Cuddy 1984*). The high frequency of Little Bluestem (*Schizachyrium scoparium*) and Black Huckleberry at this site and the presence of other species such as Indian Grass (*Sorghastrum nutans*), Puccoon (*Lithospermum croceum*), Big Bluestem (*Andropogon gerardii*), Northern Downy Violet (*Viola fimbriatula*), Beach-heath, Butterfly-weed (*Asclepias tuberosa*), Divergent Sunflower (*Helianthus divaricatus*) and Border Meadow-rue (*Thalictrum confine*) give the former Constance Bay interior sand hills a more prairie-like or dune-like flora (Porsild 1941; Breitung 1957; White 1979; Boyd and Cuddy 1984*), although many species characteristic of the sand barrens further up river were present. Similar sand barrens with Jack Pine on Calumet Island, also in the Ottawa River have yet to be inventoried.

Sand barrens similar to those of the middle Ottawa valley are scattered through the boreal forest region of northern Ontario and Quebec. The Kazubazua sand plain of western Quebec for example, is strikingly similar to the middle Ottawa valley sites. Although there is little information on Ontario boreal forest sand barrens, they generally appear to have fewer vascular plant species than the middle Ottawa valley sites. They are conspicuously lacking rare species such as *Polygonella articulata*, *Cyperus houghtonii*, and *Juncus greenei*. The higher richness of Ottawa valley sites may be attributable to the extensive occurrence of sand barrens in this area as well as post-glacial phenomenon such as disturbed open habitats (dunes and bars) associated with the Champlain Sea (Gadd 1987). Use of the area as a major east-west transport route with resultant maintenance of natural openings near campsites and introductions of plants by humans could also have contributed to the relatively rich flora (e.g., Reznicek 1983).

Open sandy habitats also exist in the lower Ottawa valley, but these, including some near the Mer Bleue bog in Gloucester/Cumberland, near Bourget (the "Bourget Barrens"), and near Casselman (particularly in the LaRose forest area) have a higher water table than the middle Ottawa

TABLE 4. Mean % frequency of species occurring in more than 1 of 25 quadrats at four sites. Cover > 30% appear in boldface.

Species	Wilbe	Petawa	Bonnec	L. Traver
Agrostis scabra	5.4	0.0	0.0	0.0
Ambrosia artemisiifolia	2.6	0.1	0.2	0.0
Amelanchier spp.	7.6	6.4	22.0	11.3
Arctostaphylos uva-ursi	2.4	0.0	2.0	1.0
Bulbostylis capillaris	0.4	0.0	0.0	0.0
Carex lucorum	25.4	**36.1**	**38.4**	**41.6**
Carex tonsa	0.3	0.2	0.2	0.0
Comptonia peregrina	22.6	3.9	**46.8**	11.8
Cyperus houghtonii	0.3	0.0	0.0	0.0
Danthonia spicata	22.1	19.0	26.8	19.0
Fragaria virginiana	7.3	0.0	0.0	0.0
Hieracium piloselloides	6.2	0.0	0.0	0.0
Juncus greenei	0.5	0.0	0.0	0.0
Muhlenbergia glomerata	4.4	0.0	0.0	0.0
Oryzopsis pungens	8.2	0.4	5.6	1.1
Panicum columbianum	3.4	0.8	0.4	0.0
Panicum cf. *linearifolium*	2.9	0.0	0.2	0.2
Polygonella articulata	2.9	0.0	0.0	0.0
Potentilla argentea	9.6	0.1	0.0	0.0
Prunus susquehanae	22.1	11.0	**41.6**	11.9
Pteridium aquilinum	6.3	0.2	0.4	0.6
Rubus allegheniensis	9.8	0.0	0.0	0.0
Solidago hispida	3.7	8.5	0.2	0.0
Solidago nemoralis	1.9	0.0	0.3	0.0
Vaccinium angustifolium	**30.0**	16.6	**42.5**	**33.6**

valley sites studied here because they are flat and underlain by impermeable marine clays. They were probably created and are maintained by fire and periodic flooding and were apparently surrounded by lower areas dominated by (Speckled Alder) *Alnus incana* (L.) Moench ssp. *rugosa* (Duroi) Clausen. *Pinus banksiana* is altogether absent from these sand barrens.

The lower Ottawa valley sand barrens support some unusual mesic species absent or rare in the apparently drier middle Ottawa valley, such as *Polygala sanguinea* L., Hudson Bay Bulrush (*Scirpus hudsonianus* (Michaux) Fern.), Ragged Orchis (*Platanthera lacera* (Michaux) G. Don), Closed Gentian (*Gentiana andrewsii* Griseb.) and Fringed Gentian (*Gentianopsis crinita* (Froelich) Ma). Among the significant species present in both areas are *Cyperus houghtonii* and *Juncus greenei*. Most remnants of the lower valley sand barrens are dominated by *Danthonia spicata*, *Carex* cf. *pensylvanica* and *Pteridium aquilinum*.

Sand barrens in the Trent valley of eastern Ontario (Catling and Catling 1993) are similar to some of the sites described here in both dominants and prevalent vegetation, but they lack *Amelanchier* spp. and *Vaccinium* spp. and are dominated by graminoids and *Pteridium aquilium*. The Trent sites also differed in composition, having a few southern and western species that do not reach the middle Ottawa valley.

Boreal heath barrens described in New York state (Reschke 1990) are apparently very similar to the middle Ottawa valley sand barren sites, but differ in being more strongly dominated by shrubs. Some characteristic species of the Ottawa valley sites not listed for the New York examples include species of *Amelanchier*, *Comptonia peregrina*, *Danthonia spicata* and *Prunus susquehanae*. Other sand barren community types in New York state are associated with Pitch Pine and Oak scrub and include a large number of southern and eastern taxa not present in the Ottawa valley sites (Reschke 1990).

Sand barrens in the maritime provinces (e.g., Hall and Aalders 1968) differ in being dominated by heaths, particulary *Kalmia angustifolia* L. and *Vaccinium angustifolium*, with *Spiraea latifolia* (Aiton) Dippel and *Spiraea tomentosa* L. being prominent. They also have a number of eastern species that do not extend as far west as the middle Ottawa valley sites, such as *Rhododendron canadense* (L.) Torr. and *Solidago puberula* Nutt. *Carex foenea*, prevalent on the Ontario sites, does not extend east of the Ottawa valley. Thus there appear to be substantial differences in dominance and composition of sand barren vegetation from east to west, although eastern and western sites do have

prominent species in common such as *Danthonia spicata* and *Pteridium aquilinum.*

Extent, maintenance and origin of the dry, sandy openings in the middle Ottawa valley

In general, the sandy openings occupy the sand barrens and spillways illustrated by Chapman and Putman (Chapman and Putman 1984), but the more persistent and perhaps richest openings were probably in the larger areas of sand deposits such as that around Petawawa. With modification of the landscape through the suppression of fires, both natural and human-caused, as well as reforestation and use of landscapes for livestock and other purposes, it is difficult to assess the extent of natural sandy openings in pre-Columbian times. An adequate search of historical records was beyond the scope of the present study. However, judging by their diverse native flora, persistence, and resistance to colonization by trees, many of the complexes of sandy openings in the middle Ottawa valley have existed for a long time, possibly for thousands of years. Periodic drought alone may have been enough to prevent encroachment of forest, but fires probably also contributed to the maintenance of larger openings. In the Petawawa area, anthropogenic disturbances may have played a role in maintaining open areas. It is also possible that periodic insect outbreaks such as Jack Pine Budworm (*Choristoneura pinus*) reduced forest cover. It is of interest that the middle Ottawa valley is one of the drier summer regions of southern Ontario, receiving an average of only 12 inches of rain from May through to September (Brown et al. 1980). This drier climate may also have contributed to the maintenance of dry natural openings.

Conclusions

The sand barrens of the middle Ottawa valley are apparently long persisting, distinctive natural habitats dominated by native species. In addition to significant fauna such as Kirtland's Warbler (Speirs 1985; Peck and James 1987) and various arthropods, the sand barrens have a significant flora. These communities have been under-emphasized in planning for representative habitat protection.

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Notes

Defense of One Twin Calf against Wolves, *Canis lupus*, by a Female Moose, *Alces alces*

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Stephenson, Thomas R., and Victor Van Ballenberghe. 1995. Defense of one twin calf against Wolves, *Canis lupus*, by a female Moose, *Alces alces*. Canadian Field-Naturalist 109(2): 251–253.

Three Wolves (*Canis lupus*) were observed attacking an adult cow Moose (*Alces alces*) with neonatal twins on the Copper River Delta, Alaska, during summer 1993. The cow successfully defended one calf from predation but the other was killed in a stream after fleeing from the cow. The cow and the remaining surviving calf moved to the stream and established a superior defensive position and both survived the Wolf attack.

Key Words: Wolf, *Canis lupus*, Moose, *Alces alces*, calf, predation, predator avoidance, behavior, Alaska.

Although Brown Bears (*Ursus arctos*) are believed to be the primary predator of neonatal Moose (*Alces alces*) calves on the Copper River Delta (MacCracken 1992) and other areas of Alaska (Ballard et al. 1981), Wolf predation of Moose calves is common in some areas of Alaska (Gasaway et al. 1983). However, we know of only two published observations of Wolf predation on neonatal Moose calves (Atwell 1964; Shelton 1966) and none of predation on neonatal twins. Observations of Wolf predation on Moose calves during winter are rare but occur more frequently (Mech 1970) due to the greater frequency of winter flying by biologists and improved sightability on snow-covered ground. Observations of predation can provide insight into the mechanisms resulting in successful or failed attempts by predators and escape behavior of prey.

The attack described here occurred on 3 June 1993 on the Copper River Delta, located adjacent to eastern Prince William Sound, Alaska, between 60° and 60°30'N latitude and 144°W longitude. MacCracken (1992) provided a detailed description of the study area.

Observations

The first author observed three Wolves from a Cessna 185 fixed-wing aircraft in the process of attacking a cow Moose with neonatal twins (approximately one-week old). Of the three Wolves, one was a radio-collared female black Wolf (Number 01), one was a radio-collared female gray Wolf (Number 02), and one was an uncollared gray Wolf (Number 03; sex unknown). The two radio-collared Wolves had been captured in March 1993 and at that time the gray female had a preexisting severely dislocated tibiotarsal joint, with the bone protruding through the skin; based on her age and future locations at a den (at which pups were produced) she appeared to be the alpha female. At capture, the black female was either a pup or yearling.

At 20:21, three Wolves encircled a cow Moose with twins and alternately and/or jointly rushed them. The Moose were in a low willow (*Salix* spp.)/Sweetgale (*Myrica gale*) habitat type, adjacent to a small circular patch of tall closed Alder (*Alnus crispa*)/willow. The dam diligently kept the twins together and defended them by rushing the Wolves and kicking with her forelegs.

After 2 min., one Wolf rushed in, grabbed one calf, and knocked it down but was immediately chased away by the dam. The Wolves continued the attack and were periodically pursued by the dam up to 10-20 m from the twins. The dam distanced herself from the twins more frequently in pursuit of the Wolves and may have occasionally lost sight of the twins. However, she primarily stood over the twins. As time passed, the dam's frequency of pursuit of the Wolves increased as did separation of the twins. Occasionally, one calf tried to follow the dam.

At 20:31, while the dam was in pursuit of a Wolf, one calf fled toward a large glacial stream located 100 m to the east. The Wolves appeared not to detect this movement, but Wolf 02 began to follow it about the time the calf reached the stream. As the calf swam across the stream, the Wolf quickly swam after it. The Wolf soon reached the calf but it swam downstream about 30 m before the Wolf reached it again. Then, the calf escaped and swam upstream 10 m before the Wolf seized it by the neck, and with some effort, pulled it over to a silt beach.

The Wolf then began consuming the calf which was still alive and moving its legs. During the Wolf's pursuit and capture of the calf, the two remaining Wolves unsuccessfully continued their harassment of the other Moose. The dam, now with a single calf, was more successful at keeping the calf under her and protecting it. The Wolf dragged the dead calf about 50 m west into willow/Sweetgale (WISW) and continued feeding.

At 20:45, Wolves 01 and 03 ceased intensive harassment of the Moose but remained within 40 m of them. The Moose were still in their initial location in WISW, adjacent to the closed Alder/willow (CAW) stand. Wolf 01 trotted over to the stream where Wolf 02 had pursued the calf into the water, travelled the bank downstream to where she had removed the calf from the stream and proceeded directly to where Wolf 02 was feeding on the calf. Wolf 01 tried to feed and was minimally tolerated by Wolf 02. Wolf 01 then returned to the location of the adult and calf Moose. Meanwhile, Wolf 03 sat and observed the Moose from a distance of 50 m. As Wolf 01 approached the dam, she was immediately and forcefully repelled.

At 20:54, the dam began to move her calf toward the stream, but after travelling 30 m, Wolf 03 resumed pursuit and the Moose, now in open low WISW, retreated to taller WISW. Shortly thereafter, all three Wolves returned to harass the Moose. However, after another 2 min., Wolf 01 ran to the unattended calf carcass, fed, then dragged the carcass 50 m west into dense WISW where she was no longer visible to us. Within 3 min., Wolf 02 returned to the location where it had left the calf carcass, then headed into the dense WISW. Wolf 03 departed from the vicinity of the Moose and disappeared in willow while travelling west; it was not observed in the vicinity of the calf carcass.

At 21:08, the dam began to depart for the stream but the calf appeared reluctant to cross the more open WISW and stayed back. However, after 2 min. of hesitation, the dam and the calf walked over to the stream and stepped into the edge of the water. Two min. later, Wolf 02 travelled up the creek bank and walked around the Moose who remained in the stream. Continuous observation ceased at 21:17 because none of the Wolves were visible and the Moose remained in the stream.

Wolves 01 and 02 remained in the vicinity of the cow and calf Moose up to 22:30. At that time Wolf 01 was mildly harassing the cow from the bank. The cow soon rushed out of the water, chased Wolf 01 away, and returned to the calf. Wolf 02 was not visible but her signal came from the vicinity of the calf carcass. The cow and the calf were still standing in the stream when we departed at 22:35. No Wolves were visible.

Discussion

The departure of the calf from its mother suggests one event leading to successful Moose calf capture by Wolves. If the calf had remained with its mother, she may have been successful in defending both calves. Alternatively, trying to defend both may have resulted in both calves being lost. The calf that ran could have successfully escaped only to hide and rejoin the dam later. However, for a calf of this age that scenario seems unlikely. Escape behavior by very young calves should be selected against in species such as Moose that are capable of defending offspring.

This attack provides additional insight into habitat selection as it relates to predator avoidance and evasion. When the attack occurred, the Moose remained adjacent to the CAW habitat type. Although this was a small stand, it limited the number of directions from which the Wolves could attack. The dense structure of alder and willow stems probably made it difficult for Wolves to rush the cow, and to rapidly escape her charges.

The dam and the calf both hesitated when crossing the less dense WISW to reach the stream bank. Once the edge of the stream was reached, the Moose were in a superior defensive position. It is unlikely that Wolves would try to attack from the stream side (as indicated by the behavior of these Wolves), especially by swimming. Thus, the Moose needed to defend an arc of only 180°. Therefore, it appears that use of stream banks by cows with calves is advantageous in terms of predator defense. Moose have been documented using open water to escape Wolf predation (Mech 1970; Gasaway et al. 1983). However, there are disadvantages to remaining along stream banks on the Copper River Delta because they are commonly used travel corridors (due to the better drainage, less standing water, and greater shrub hiding cover) by many species, particularly mammalian predators (unpublished data). Therefore, use of stream banks might increase the probability of detection. Clearly, there are trade-offs between predator defense and avoidance.

This incident also documents the ability of Wolves to recover from disabling injuries in the wild. The recovery and subsequent predatory success of the gray collared female (02) is notable. Her speed in avoiding the charges of the adult Moose, and in pursuing and capturing the calf, revealed minimal disability from her previous injury. Furthermore, the three Wolves involved in this attack belonged to a pack of five adults which concurrently occupied a den that produced a minimum of four pups. Although the alpha female was injured and nursing pups, she was also very capable of obtaining food for the pack.

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Wolf, *Canis lupus*, Predation on Dusky Canada Geese, *Branta canadensis occidentalis*

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Stephenson, Thomas R., and Victor Van Ballenberghe. 1995. Wolf, *Canis lupus*, predation on Dusky Canada Geese, *Branta canadensis occidentalis*. Canadian Field-Naturalist 109(2): 253–255.

On two occasions on the Copper River Delta, Alaska, radio-collared Wolves (*Canis lupus*) were observed locating and consuming Dusky Canada Goose (*Branta canadensis occidentalis*) eggs. On a third occasion, a pair of Wolves killed three geese. Non-mammalian Wolf prey on the Copper River Delta is abundant relative to other areas. Although geese may be less profitable than ungulate prey, there is less risk associated with their capture and the availability of such alternate prey may lead to decreased Wolf predation on Moose at this site. Wolf predation on geese may be additive to other mortality factors or compensatory due to displacement of coyotes.

Key Words: Wolf, *Canis lupus*, Dusky Canada Goose, *Branta canadensis occidentalis*, predation, alternate prey, Alaska.

Although scat analyses in several studies have identified Wolf (*Canis lupus*) predation on birds (Ballard et al. 1987; Fuller 1989; Peterson et al. 1984), no published observations of Wolf predation on geese are available. Utilization of non-mammalian prey by Wolves appears uncommon. However, most Wolf predation/food habits studies have emphasized winter foraging ecology, particularly as monitored through field observations. Direct observation avoids some limitations inherent in scat analysis by providing data on kill rates, killing versus scavenging behavior, and detection of highly digestible foods. Less is known about Wolf summer foraging behavior, when proportionately more non-ungulate prey may be available and utilized.

The incidents described here occurred on the Copper River Delta, located adjacent to eastern Prince William Sound, Alaska, between 60° and 60°30′N latitude and 144°W longitude. MacCracken (1992) provided a detailed description of the study area. The first author observed the incidents while circling overhead in a Piper PA 18-150 "Supercub" fixed-wing aircraft.

Observations

At 21:10 on 21 May 1992, a radio-collared adult female Wolf flushed an adult Dusky Canada Goose (*Branta canadensis occidentalis*) from a nest and consumed the eggs. The Wolf then travelled 300 m, flushed a second goose from a nest at a distance of 50 m and, after failing to locate the nest during a quick search, departed the area. A ground search the following day revealed that the destroyed nest initially contained at least four eggs (based on eggshell

remains). The intact nest contained five eggs, with an additional eggshell 1 m from the nest; the eggshell was intact except for a 2 cm hole, characteristic of avian predation (Rearden 1951). Both nests were located in sedge (*Carex* spp.) meadows adjacent to willow (*Salix* spp.)/Sweetgale (*Myrica gale*) plant communities.

During 11:15–11:30 on 28 May 1992, a radio-collared adult female Wolf consumed the eggs of three goose nests. The nests were located by sequentially flushing the adults as the Wolf searched a broad sedge meadow. After consuming the third clutch, the Wolf behaved in an animated manner and chased its tail.

On 8 August 1993, two radio-collared adult Wolves, male and female, were located in an area with a high concentration of molting Dusky Canada Geese. Observations were made between 19:20 and 19:45. The Wolves were traveling about 50 m apart with the female leading and were headed in the direction of a large pond (1 ha) to the NW occupied by at least 50 geese.

When the Wolves were within 100 m of the pond, they separated; the female crouched and moved a short distance through a low willow/graminoid plant community. Some geese on the perimeter of the pond apparently detected her because there was a sudden large flush into the pond. The female Wolf then ran to the pond, jumped in, and began to chase geese. The male Wolf circled to the opposite side of the pond and entered the water when the geese were pushed there. By this time, about one-half of the geese had flown to an adjacent pond (75 m to NW) and the Wolves were chasing the remainder. Most of the geese were able to fly, but apparently not well enough to reach the other pond easily because they were still molting. The shallow water in the pond enabled the Wolves to leap (as opposed to swim) and thereby exhaust the geese. Precipitation was 46% below normal during June through mid-August 1993 (National Oceanic and Atmospheric Administration 1993) and likely resulted in lower than normal pond levels.

After 5 minutes of pursuit, the male captured a goose, carried it to the shore, and returned to the pond. During the next 6 minutes, working as a team, the female caught a goose and the male caught a second goose. By this time, most of the geese had flown to a larger adjacent pond 75 m to the NW and the female crossed the narrow strip of land between the ponds and began chasing geese in the shallow end of this pond. The geese moved to deeper water, however, and the female was forced to swim, and quickly fell behind. The female returned to the carcass of the first goose and began consuming it. The male was still consuming the second goose he caught as we departed at 19:45.

Discussion

Wolves in most locations consume primarily ungulate prey (Ballard et al. 1987). Huggard (1993) found that 9% of the biomass in the diet of Wolves in Banff National Park was non-ungulate in summer. In contrast, Fuller (1989) determined that Beaver (*Castor canadensis*) composed 20-47% of the items in scats in Minnesota during summer. Potential non-ungulate prey is abundant on the Copper River Delta (CRD). The CRD is the primary nesting ground for the Dusky Canada Goose (Cornely et al. 1985), 7% of the world's Trumpeter Swans (*Cygnus buccinator*) (Hansen et al. 1971), and numerous other waterfowl. The available biomass of non-mammalian prey, including waterfowl, during summer is substantial. Conant and Groves (unpublished report, U. S. Fish and Wildlife Service, Juneau, Alaska, 1994) estimated 26 584 ducks (one of the highest densities in Alaska), Jarvis (unpublished report to Dusky Canada Goose Subcommittee, Pacific Flyway Study Committee, Corvallis, Oregon, 1994) estimated 15 466 geese, and Groves and Conant (unpublished report, U. S. Fish and Wildlife Service, Juneau, Alaska, 1995) estimated 816 Trumpeter Swans on the CRD. Crouse (unpublished report, U. S. Forest Service, Cordova Ranger District, Alaska, 1994) reported that apparent nest predation on Dusky Canada Geese on the west CRD was 69% and that nests were destroyed primarily by avian predators, Brown Bears (*Ursus arctos middendorffi*), and Coyotes (*Canis latrans*). In addition to the predation incidents described in detail above, T.R.S. observed radio-collared Wolves on the CRD consuming Trumpeter Swan eggs on one occasion and located goose and eggshell remains at Wolf den sites. Furthermore, use of non-mammalian prey extended to consumption of salmon (*Oncorhynchus* spp.) during late summer through early winter (unpublished data).

The availability of geese to Wolves also is determined by access. During summers with low precipitation such as 1993, the lower water level in ponds that geese rely on for predator avoidance during molting reduces the ability of geese to escape mammalian predators capable of running in the shallower water.

Although less profitable than ungulate prey like Moose (*Alces alces*), prey such as geese involve less risk to capture. The dangerous prey hypothesis (Forbes 1989) predicts that the high handling time for dangerous prey should reduce returns, especially if less dangerous prey are available. Mech and Nelson (1990) and Weaver et al. (1992) documented Moose killing Wolves, and Mech (1970) and Haugen (1987) presented data on the high number of Wolf carcasses with injuries obtained from being kicked by ungulates.

Messier (1994) discussed two scenarios regarding the effect of alternate prey on Moose-Wolf interactions, both of which can be applied to the CRD. First, predation on geese may decrease predation on Moose by lowering the functional response (Holling 1959), whereby Wolves feeding on geese consume fewer Moose per unit of time. Secondly, the introduction of Moose to the CRD during 1949-1958 (MacCracken 1992) allowed Wolves, which were previously absent, to colonize the area and thus introduced Wolf predation on geese there. Berger and Wehausen (1991) discussed increased predation on sensitive prey populations following increases in alternate prey and described a predator/prey disequilibrium in the Great Basin Desert. Similarly, vegetation succession and alternate prey availability have altered predator/prey relationships on the CRD and have disrupted community dynamics. Ecosystem structure, which once favored geese, has shifted in favor of other species.

Further research is needed to assess predation on Dusky Canada Geese because, in addition to the above, increased Wolf populations may suppress more abundant and effective waterfowl predators such as Coyotes (Mech 1970). Potential effects of Wolf predation should not be exaggerated relative to the effects of declining nesting habitat and more abundant goose predators. Undoubtedly, the 1964 earthquake in the area around the Gulf of Alaska, which altered vegetation succession (Thilenius 1990) and resulted in a decline in goose nesting habitat, has had a detrimental effect on goose productivity. Overall, Wolf predation may be additive or compensatory depending upon the levels of other mortality factors such as non-Wolf predation, weather, human hunting, and habitat loss.

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Summer Above-Ground Movements of Northern Pocket Gophers, *Thomomys talpoides*, in an Alfalfa Field

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Proulx, Gilbert, Michael J. Badry, Pamela J. Cole, Randal K. Drescher, Alfred J. Kolenosky, and Iwona M. Pawlina. 1995. Summer above-ground movements of Northern Pocket Gophers, *Thomomys talpoides*, in an alfalfa field. Canadian Field-Naturalist 109(2): 256–258.

Northern Pocket Gophers' (*Thomomys talpoides*) above-ground movements were studied with a fluorescent U.V. powder spread over 10 to 18 burrow systems from 1 June to 8 September 1993 in an alfalfa field near Vegreville, Alberta. Gophers did not limit their surface activities to burrow openings. The number of burrow systems with above-ground movements over a 48-h period decreased from June (90%) to July (50%), August (17%), and September (0%). Gophers exiting their burrow system produced trails with an average length of 28.7 (SE = 2.4) cm in June, 16.8 ($\pm$ 4.1) cm in July, and 23.0 ($\pm$ 5.7) cm in August. The mean sums of trail lengths per burrow system were significantly greater ($P < 0.05$) in June (130.8 $\pm$ 32.6 cm) than in July (43.6 $\pm$ 16.5 cm) and August (46.0 $\pm$ 12.0 cm). In late summer, surface movements were almost nonexistent. The number and extent of gophers' above-ground movements may be related to the presence of vegetative cover and a gradual change in feeding behavior over summer.

Key Words: Northern Pocket Gopher, *Thomomys talpoides*, alfalfa field, fluorescent marker, summer movements.

Because of the fossorial habits of the Northern Pocket Gopher (*Thomomys talpoides*), little is known of its summer movements and activities. Aldous (1951) reported that gophers gathered their food largely from underground. They would also feed from the mouths of their burrows, their body length being the maximum radius of operation. Also, because pocket gophers are vulnerable to predation, it is believed that most of their above-ground movements are associated with the dispersal of young animals (Howard and Childs 1959). In winter, the presence of a continuous snow cover is also related to above-ground movements (Vaughan 1963).

However, Miller (1948) and Reid et al. (1966) indicated that gophers opened holes from the underground tunnel to the surface, and consumption of above-ground vegetation parts has been previously reported (Miller and Bond 1960; Ward 1960; Ward and Keith 1962). Proulx et al. (1995), in a study of gophers' behavioral activities in a simulated environment, found that gophers were not reluctant to feed and move on surface. Out of 48 h of continuous observations, gophers spent an average of 2.7 h feeding or gathering food on surface. Furthermore, gophers are preyed upon in summer by birds of prey (Fitch et al. 1946; Evans and Emlen 1947; Turner et al. 1973, Smith 1981) and they are sometimes captured in cocked pocket gopher traps left on the ground (P. Cole, unpublished data).

Considering the divergence of opinions, this study aimed to determine the ocurrence and extent of gophers' above-ground movements in summer.

Methods

The study was carried out from 1 June to 8 September 1993 in an alfalfa field near Vegreville, Alberta. We monitored the above-ground movements of gophers at 10 active burrow systems in June and July, 17 in late August, and 18 in early September. Burrow systems were at least 5 m apart from each other and corresponded to well-defined clusters of mounds and earth plugs. Mounds were concentric piles of soil pushed to the surface of the ground by pocket gophers as they feed and develop or extend their underground burrow system (Reid et al. 1966). Earth plugs were holes that had been filled with soil by gophers returning from the surface to the underground tunnel of their burrow system (Reid et al. 1966). Gopher movements were monitored over a 48-h period using a fluorescent U.V. tracking powder (Nicholls Industrial and Security Supplies, Longueuil, Quebec) spread along the edges of the mounds and earth plugs. On each of the following two mornings, we placed a tarp over the burrow systems and monitored the dispersal of powder with ultra-violet light. Fluorescent trails were carefully mapped and their linear distance was recorded. If a trail ended at a feeding site, cut plants were carefully examined for traces of fluorescent powder and, when possible, compared to leftover pieces of vegetation found at the entrance of earth plugs. Finally, new excavation activities were recorded daily. After the first day, we spread fluorescent powder (a color different from the one used on the first day) around new mounds and earth plugs and around those that were disturbed the previous night by gophers' activities.

Because the data were gathered over a short period of time, rain did not affect our study. The vegetation was 30 to 40 cm high in mid-June. In mid-July, after the first alfalfa harvest, and in late August and early September, after the second harvest, vegetation was 10 to 15 cm high. The mean number of mounds, plugs and trails per burrow system, and the mean length of fluorescent trails were compared from month to month with a t-test (Dixon and Massey 1969). Contingency tables were used to test for independence between the months of the year, the number of burrow systems where above-ground movements had been recorded, and the amount of new building activity (Dixon and Massey 1969).

Results

Burrow Components

The mean number of earth plugs/burrow system decreased from June to September (Table 1). There was no significant difference ($t = 1.404$, $P > 0.05$) between the number of plugs/burrow system in June and July. However, the mean number of plugs was significantly ($P < 0.05$) less later in the summer (Table 1).

The proportion of newly built mounds and earth plugs was dependent on the time of year ($\chi^2 = 9.660$, df = 3, $P < 0.005$). In June and July, gophers built a similar number of earth plugs and mounds over 48 hours (Figure 1). In August and September, they almost exclusively built mounds (Figure 1).

Above-ground Movements

The number of burrow systems with above-ground movements depended on the time of year ($\chi^2 = 29.100$, df = 3, $P < 0.005$) and decreased from June to September (Table 1). The mean number of gopher fluorescent trails per burrow system was similar ($t = 1.485$, $P > 0.05$) in June (4.5 ± 2.7 trails) and July (2.6 ± 1.1 trails). In August, only 3 burrows had 2 trails each and in September, no trails were found. The mean linear length of the trails decreased from June to August (Table 1). However, a significant difference was obtained only between June (28.7 ± 2.4 cm) and July (16.8 ± 4.1 cm) means ($t = 2.454$, $P < 0.05$). During the 48-h study periods, the mean sums of trail lengths per burrow system were significantly greater in June (130.8 ± 32.6 cm) than in July (43.6 ± 16.5 cm) ($t = 2.387$, $P < 0.05$) and August (46.0 ± 12.0 cm) ($t = 2.441$, $P < 0.05$). There was no difference between July and August means ($t = 0.101$, $P > 0.05$). On twenty (49%) of the 41 trails found in June, and 12 (93%) of the 13 trails recorded in July, freshly clipped plants were found.

Discussion

Because of the fossorial habits of pocket gophers, it is commonly believed that their food is largely procured underground (Ellison and Aldous 1952). Although gophers are known to take vegetation from above ground (Aldous 1951), previous researchers surmised that animals foraged on surface only near burrow openings (Vaughan 1967). According to Bailey's (*in* Aldous 1951) observations, pocket gophers never forage further out than they can reach by keeping their hind feet in the burrow entrance. Aldous (1951) noted that nearly all vegetation within a radius of 20 cm from the tunnel opening is removed before the gophers begin to pile up their mound.

Our June observations do not indicate that gophers spend much time digging and expanding their tunnel system. This is in agreement with Miller and Bond (1960) who suggested that the lack of burrowing activity during June and July may be explained by the fact that the adults are involved in caring for their young and that surface foraging may replace burrowing and construction of feeding tunnels.

Our fluorescent study clearly indicated that gophers did not limit their feeding activities to the burrow openings. In fact, fluorescent trails were, on average, beyond the 20 cm distance reported by Aldous (1951). It appears that above-ground movements are related to the presence of cover. In winter, snow protects gophers moving above ground (Vaughan 1967). In summer, high vegetation can

TABLE 1. Number of pocket gopher burrow systems, number of plugs per burrow system, number of burrows with above-ground movements, mean sum of trail lengths (cm) per burrow system, and mean linear length (cm) of gophers' fluorescent trails, from June to September 1993.

		Number of Earth plugs/burrow		Burrows with above-ground movements			Linear length of fluorescent trails (cm)			
					Sum of trail lengths/burrow (cm)					
Period	Number of burrows	x̄	SE	n (%)	x̄	SE	n	x̄	SE	Range
June	10	5.7	0.30	9 (90)	130.8	32.6	41	28.7	2.4	8 - 81
July	10	4.5	0.80	5 (50)	43.6	16.5	13	16.8	4.1	2 - 54
August	17	0.1	0.08	3 (18)	46.0	12.0	6	23.0	5.7	6 - 44
September	18	1.3	0.30	0 (0)	0.0	0.0	0	0.0	0.0	0

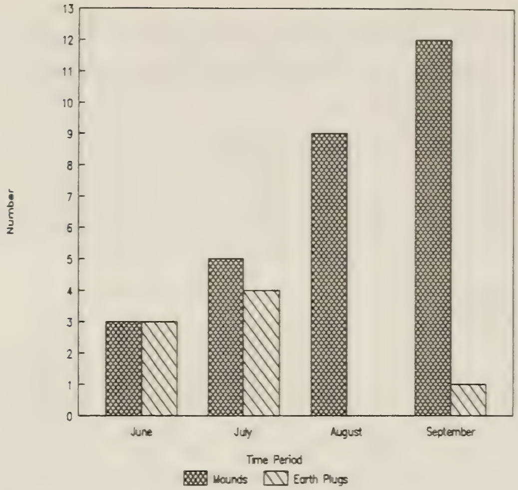

FIGURE 1. Earth plugs and mounds built by gophers during 48-h study periods, in June, July, August and September 1993.

also provide the necessary cover to protect gophers from predators. Our study showed that in July, when the vegetation was 10 to 15 cm high, gophers' above-ground movements were shorter than in June, when the vegetation was at least 30 cm high. In August, above-ground movements were also shorter than in June. However, because of the small August sample size and the great variability of the data, no statistical difference was detected. Ward's (1960) findings that consumption of above-ground vegetation peaked in June and declined thereafter coincide with our data on above-ground movements.

The frequency and extent of above-ground movements was also dependent on the time of year. In August and September, these movements were almost nonexistent. This change in gophers' behavior coincided with a significant decrease in the number of earth plugs per burrow system and an increase in mounding. This may be associated with the dispersal of young from the parent burrows and a return to a system of individual territories (Miller and Bond 1960; Reid et al. 1966), and a gradual change in behavior from surface feeding to subterranean feeding as the vegetation matures and the leaves and stems become less palatable (Miller and Bond 1960).

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First Record of the Butterfly *Euchloe naina* (Lepidoptera: Pieridae) from North America

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Kondla, Norbert G., and Jonathan P. Pelham. 1995. First record of the butterfly *Euchloe naina* (Lepidoptera: Pieridae) from North America. Canadian Field-Naturalist 109(2): 259.

The presence of the Green Marble (*Euchloe naina*) Kozhantschikov, 1923, is reported in the Ogilvie Mountains of Yukon Territory, Canada. This butterfly was previously known to occur only in central and northern Asia and thus represents an addition to the known North American butterfly fauna.

Key Words: Green Marble, *Euchloe naina*, Lepidoptera, Pieridae, Ogilvie Mountains, Yukon Territory.

The Green Marble (*Euchloe naina* Kozhantschikov, 1923) was first collected in North America from 17 to 28 June 1972 by E. M. Pike at kilometre 131 of the Dempster Highway, Yukon. Since then, occasional specimens have been collected by various researchers including a few by N. G. Kondla on 17 June 1987 at kilometre 131 Dempster Highway and some by Pelham and L. Crabo in the Windy Pass area (kilometre 146-156 Dempster Highway) from 9 to 28 June 1989. In 1993 Kondla explored these two areas more carefully between 7 and 17 June. He found that *E. naina* is abundant on some steep, dry, barren limestone scree mountain slopes at elevations from 1050 m to 1350 m.

Adults take nectar avidly at flowers of *Parrya nudicaulis* (L.) and females oviposit on *Braya humilis* (C. A. Mey) as well as *Draba* sp. In the breeding habitat both males and females were observed to fly slowly about 15 cm above the scree surface, even on wind-free days. The occasional individual in dispersal mode was seen flying at heights of 50 to 100 cm along valley bottom rocky stream channels and roadsides. In these lower elevation sites adults flew sympatrically with *Euchloe creusa* (Doubleday) and displayed the same flight behaviour. *Euchloe creusa* was not seen on the steep scree slopes.

Comparison of specimens with individuals of the described North American *Euchloe* species [*E. creusa* (Doubleday), *E. ausonides* (Lucas), *E. hyantis* (W. H. Edwards), *E. ogilvia* Back, *E. olympia* (W. H. Edwards) and *E. guaymasensis* Opler] revealed that the Yukon taxon is unlike any described North American species. This northern Ogilvie Mountains population of *Euchloe naina* has a number of distinctive phenotypic features that allow for easy separation from other northwestern *Euchloe*. *Euchloe naina* has dense black scaling along the dorsal forewing costal margin from the base to the discal cell bar; the dorsal hindwing has a very pronounced linear smudge of black scales; the ventral hindwing is 80% to 95% solid dull green; the ventral hindwing veins are green rather than yellow; and the forewing shape is blocky rather than pointed. Both *E. ogilvia* and *E. ausonides* have the ventral hindwing green color in distinct bands while *E. creusa* has ventral hindwing green color as fine marbling and is smaller in size. Fresh individuals of E. *naina* are decidedly nacreous on the dorsal surface and white areas of the ventral hindwing are strongly silvered. The females are strikingly distinctive due to extensive melanic scaling on the dorsal surface. Back (1990) provides color plates of both *E. naina* and *E. ogilvia.*

The species and subspecies status of Palearctic *Euchloe* have been in flux over the past 100 years. *Euchloe naina* has been variously placed as a subspecies of *E. ausonia* (as were many other now valid *Euchloe* species), a subspecies of *E. simplonia* Freyer (Back 1990), and as a valid species, but no thorough revision or analysis appears in the literature to unequivocally support any one of these interpretations. Consistent with the treatment by Tuzov (1993), we use the species name *Euchloe naina* here. Examination of color plates in Back (1990) shows that the Yukon specimens are most like his taxa *E. simplonia jakutia* and *E. simplonia naina*.

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Northern Mockingbird, *Mimus polyglottos*, at Princeton: First Successful Breeding Record in British Columbia

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MacKenzie, Jo Ann, Hue N. MacKenzie, and Madelon A. Schouten. 1995. Northern Mockingbird, *Mimus polyglottos*, at Princeton: First successful breeding record in British Columbia. Canadian Field-Naturalist 109(2): 260.

A family group of Northern Mockingbirds, *Mimus polyglottos*, was present from late July to mid-August 1993 near Princeton, British Columbia. Diagnostic photographs of a fledgling were taken. This is the first record of successful breeding of the Northern Mockingbird in British Columbia.

Key Words: Northern Mockingbird, *Mimus polyglottos*, breeding, British Columbia.

On 26 July 1993, J. A. and H. MacKenzie discovered two Northern Mockingbirds, *Mimus polyglottos*, in close association beside Highway #5A north of Princeton, 2.6 km north of the Old Hedley Road (49° 29'N, 122° 30'W), in the southern interior of British Columbia. Subsequent investigation by M. Schouten and others revealed a nest and three recently fledged young. This note documents the first successful breeding of the Northern Mockingbird reported in British Columbia.

The Northern Mockingbird is resident regularly from northern California, eastern Oregon, northwestern Nevada, northern Utah, central Illinois, central Indiana, northern Ohio, southern Pennsylvania, southern New York, southern New England, south through Baja California and Mexico, and to the Bahama Islands and Greater Antilles (American Ornithologists' Union 1983). In Canada, it is resident sporadically or locally in southern Alberta, southern Saskatchewan and southern Manitoba; it is casual in British Columbia (A.O.U. 1983). In Alberta, nests have been found at Didsbury in 1928, at Provost and Cadogan in 1964; it has probably nested at Pollockville (Salt and Salt 1976). The Alberta breeding bird atlas confirmed recent breeding at Suffield, Bindloss and Sylvan Lake (Semenchuk 1992).

In 1967, E. K. Lemon and others observed an apparent female with a nest in a garden in Victoria, British Columbia (Lemon 1968). No second adult was found, and examination of the eggs revealed them to be infertile. The nest and eggs were collected 27 July 1967 and deposited in the Royal British Columbia Museum, catalogue number E929.

On 31 July 1993, Pearl and Bruce Morgenstern relocated the adult mocking birds on the dry hillside on the west side of Highway #5A. The dominant vegetation was Saskatoon, *Amelanchier alnifolia*, with scattered trees of Ponderosa Pine, *Pinus ponderosa*, and Lodgepole Pine, *Pinus contorta*. The adult birds were observed carrying *Amelanchier* berries, Cabbage White Butterflies, *Pieris* sp., and an unidentified whitish insect to two young which had left the nest but were not yet capable of sustained flight. On 1 August, Steve and Jean Cannings, Jerry and Kim Herzig, and M. Schouten observed one fledgling in an *Amelanchier* 1–2 m from the empty nest. An adult carrying insect food (cricket species), perched on a mullein (*Verbascum thapsus*). Photographs were taken of the nest, young, and adult; these were subsequently deposited in the Royal British Columbia Museum (BC Photo #2073). In all, three fledglings were noted calling; the presence of a fourth was suspected, but not confirmed.

By the middle of August, two young were seen flying and feeding independently on *Amelanchier* berries. One adult was observed nearby. A further visit to the area in the first week of September by M. Schouten failed to reveal adults or young.

Acknowledgments

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Fatal Trauma Sustained by Cougars, *Felis concolor*, While Attacking Prey in Southern Alberta

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Ross, P. Ian, Martin G. Jalkotzy, and Pierre-Yves Daoust. 1995. Fatal trauma sustained by Cougars, *Felis concolor*, while attacking prey in southern Alberta. Canadian Field-Naturalist 109(2): 261–263.

Three radio-collared Cougars (*Felis concolor*) in Alberta died from injuries sustained while attacking prey, and a fourth may have died protractedly from such an injury. Injuries included a fractured vertebral column, punctured abdominal cavity, severe cranial trauma, and bacterial infection of the thoracic cavity.

Key Words: Cougar, *Felis concolor*, natural mortality, fatal trauma, accident.

Cougars (*Felis concolor*) are solitary predators which normally hunt prey larger than themselves. As such, they are regularly exposed to risk of serious, debilitating injury. Brown et al. (1988), Gashwiler and Robinette (1957), Hornocker (1970), and Lindzey (1987) each reported on Cougars which died from injuries apparently sustained during predation attempts on Elk (*Cervus elaphus*) or Mule Deer (*Odocoileus hemionus*). However, due to the elusive behaviour of this species, such incidents are difficult to document.

In southwestern Alberta, three incidents of fatal trauma and one incident of protracted death attributed to prey-capture attempts were documented for Cougars during a 13-year study involving radio telemetry. The victims were two subadult females, an adult female, and an adult male. The two young animals were known-age progeny of radio-collared females, and the two older Cougars had each been radio-collared for > 6 years. Ages of older Cougars were estimated based on dental characteristics described by Ashman et al. (1983) and through comparisons with known-age animals in our study.

On 4 December 1985, following a week of intense cold, a radio-collared 18-month-old female Cougar, F32, was found dead in the bottom of a minor drainage. The carcass was in lateral recumbency, with the hind legs extended and forelegs drawn underneath. Based on radio-telemetry data and snowfall chronology, we determined that she had been dead for between 4 and 9 days. Subsequent necropsy revealed a complete separation of the vertebral column between the 12th and 13th thoracic vertebrae associated with some hemorrhage and indicating a severe blow to the mid-dorsal region. Snow cover at the site was complete and allowed interpretation of the following events. The Cougar had stalked and attacked an adult Mule Deer, initially making contact about 45 m upslope of her carcass. Tracks indicated that the Cougar rode the deer for 40 m, directly downslope. At this point, Cougar hair was found adhering to the lower 50 cm of the trunk of a Lodgepole Pine (*Pinus contorta*) by which the deer tracks passed. Immediately thereafter, Cougar tracks resumed in the snow. These tracks consisted of a trough indicating that she dragged herself through the snow 20 m downslope to the site where she was found. No sign of scavengers was observed. Whether she was thrown from the deer onto the tree or was crushed between the deer and the tree could not be ascertained. The deer continued downslope for at least 200 m, and likely survived the attack.

At necropsy, this Cougar was in excellent physical condition with abundant fat deposits, indicating that death had been fairly rapid. Death may have resulted from hypothermia because of the animal's incapacity to seek shelter. F32 had been independent of her mother for eight months prior to her death. It is possible that her relative inexperience in hunting predisposed her to the accident that led to her death.

On 6 April 1990, F9, an adult female Cougar known to be at least nine years old, attacked and killed an adult cow Elk. On 16 April, the carcass of F9 was found 200 m from that of the Elk. Her carcass was in sternal recumbency, curled in a resting posture, under the branches of an Engelmann Spruce (*Picea engelmannii*). Radio-telemetry data and condition of the carcass confirmed that she had been dead for at least two days. At the time of her death, F9 was accompanied by three dependent 8-month-old juveniles.

We conducted a field necropsy on site. The left side between the 8th and 13th ribs and involving the ventral half of the rib cage was heavily contused over an area of about 8 × 25 cm. Although

the internal surface of the thoracic wall was not bruised, the left lung was very dark and appeared haemorrhagic. There was a 3 × 5 cm puncture wound in the left side immediately posterior to the 13th rib. This puncture wound angled forward across the abdominal cavity, and perforated the large intestine and stomach wall. Tree bark was observed within her abdominal cavity, in a location consistent with the trajectory of the puncturing object. Minor contusions were also discovered on the left shoulder and the left side of her head. Proximal cause of death could not be determined, but she may have died fairly rapidly from severe toxemia following perforation of the digestive tract and subsequent leakage of its contents into the abdominal cavity.

Approximately 20 m from the Elk carcass was a large Engelmann Spruce with a 3-cm branch broken off 40 cm from the trunk. Cougar hair was observed on this branch, and the branch was stained with blood and what appeared to be digestive fluids. Tracking conditions were suboptimal, but indications of a struggle were evident on the ground beside this tree. We surmise that in the struggle between the Elk and the Cougar, F9 was swung against the tree and impaled upon the broken branch. A small amount of tissue had been consumed from the Elk carcass. F9s juveniles were likely responsible for at least some of this feeding.

An adult male Cougar, M53, was found dead on 14 January 1994. He was at least 11 years old. He died during darkness between 13 January and 14 January. His carcass was found on a steep talus slope at the base of a 25 m cliff. He had sustained severe cranial injuries, several fractured ribs and a punctured lung, as well as multiple contusions and abrasions throughout his body, consistent with a fall over such a cliff. No other fractures were noted. A small amount of blood was evident on his nostrils. He was in sternal recumbency, and tracks indicated that he had survived the fall long enough to move about 2 m.

Twenty metres away, on the same slope, lay the carcass of a Bighorn Sheep (*Ovis canadensis*). This sheep had sustained severe head trauma and other injuries indicative of a fall. The sheep was a tagged individual that had been observed alive the previous day. Snow cover was complete on the sheep trails on top of the cliff. Fresh tracks of a large male Cougar, almost certainly M53, were found here, mingled with tracks of several Bighorns. These tracks indicated that M53 attacked the sheep on top of the cliff and in the struggle both animals slipped over the edge.

A 20-month-old female, F34, was found dead on 3 December 1985, 25 m from a Bighorn Sheep that she probably had killed earlier. Based on field evidence (snow tracking) and radio telemetry data, she had died not more than three days earlier. At necropsy, she had good fat reserves but an empty stomach, and her thoracic cavity contained approximately 500 ml of purulent fluid. Bacteriological culture of this fluid yielded a heavy growth of *Streptococcus canis*. This bacterium is part of the normal flora of the skin and mucous membranes of domestic carnivores (Blanchard and Wilson 1990), but it can become an opportunistic pathogen when introduced into body cavities. A small puncture wound from a branch through this Cougar's thoracic wall would seem a likely portal of entry for this bacterium from the skin into her thoracic cavity. The proximate cause of her death was toxemia. Based on the volume of purulent fluid that had accumulated in the thorax and on the amount of fat reserves still present in the carcass, the infection was estimated to have lasted about one week.

Each of these cases involved a set of circumstances that may appear unusual. However, we suggest that injury sustained while attacking prey can be a significant source of mortality for a Cougar population, because these animals normally hunt large prey. Since 1981, we have documented the deaths of 50 Cougars of 87 we have marked. Thirty-six of these were man-caused, 3 were of unknown causes, and 11 mortalities have been from natural causes. Of the 11 natural deaths, at least 3 resulted from injuries sustained while attacking prey. This suggests that in an unhunted Cougar population, as much as 27% of mortality could result from predation attempts, or possibly more if hunting mortality is compensatory to such natural deaths. These injuries may be most prevalent in young and inexperienced, or old and infirm cougars.

Acknowledgments

These observations resulted from a long-term study supported by many organizations and individuals. Major sponsors have included Alberta Fish and Wildlife Services, Alberta Recreation, Parks and Wildlife Foundation, Nova Corporation, Sarcee Fish and Game Association, Shell Canada, and World Wildlife Fund Canada. We are grateful to R.W. Schmidt for field assistance. We dedicate this paper to the memory of Orval Pall, whose devotion to this project inspired all who worked with him.

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Partial Albinism in an Island Population of Meadow Voles, *Microtus pennsylvanicus*, from Nova Scotia

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Parsons, Glen Joseph, and Søren Bondrup-Nielsen. 1995. Partial albinism in an island population of Meadow Voles, *Microtus pennsylvanicus*, from Nova Scotia. Canadian Field-Naturalist 109(2): 263–264.

Four of 276 (1.45%) Meadow Voles (*Microtus pennsylvanicus*) observed on a small island off the southern tip of Nova Scotia, were partial albinos. This is the only known observation of this colour morph in eastern Canada.

Key Words: Meadow Vole, *Microtus pennsylvanicus*, albinism, island, Nova Scotia.

Variation in Meadow Vole (*Microtus pennsylvanicus*) pelage colour has been reported by Gaines (1985). Differences in the width of the subapical band of yellow pigments on black hairs, and total number of black hairs, cause the pelage of the genus *Microtus* to vary from pale yellow to dark brown or black (Gaines 1985).

Observations were made during a study of the spatial response by Meadow Voles to the odour of Mink (*Mustela vison*) between 1 June and 31 August 1992, on Bon Portage Island, Nova Scotia, a small island (150 ha) located 3 km from Cape Sable Island, off the southern tip of Nova Scotia (43°26′N, 65°38′W). The study area measured 49m × 98m. Trap stations, consisting of one Ugglan multiple capture live trap per station for a total of 98 traps, were placed in a grid pattern with 7 m spacing. Each trap was supplied with a slice of apple and crushed oats during trapping periods. Traps were checked three times daily, and each trapping period lasted three consecutive days, at the end of which the traps were opened for two days. Captured voles were weighed, checked for reproductive status and individually identified by toe clipping. The animals were released immediately after capture. The study design was reviewed and accepted by the Acadia University Animal Care Committee.

During the study period, 276 individual Meadow Voles were captured. Four of the 276 voles captured (1.45 %) were "partial" albinos, with creamy white pelage, pink skin and dark eyes (that appeared "pinkish" when closely examined). One partial albino vole (an adult male) was housed in the Animal Facilities at Acadia University, Wolfville, Nova Scotia, until its death on 18 October, 1993. The specimen (Number MA2059) is held at the Robie Tufts Museum at Acadia University.

This is the only known observation of this colour morph in eastern Canada. Clark (1938), Owen and Shackelford (1942) and Holt (1990) have reported blond or "cream" voles, but there was no evidence of "pinkish" eyes in their animals.

Why would the Meadow Voles on Bon Portage Island have a unique colour morph present in its population at such high frequency? Recent genetic work by Stewart and Baker (1992) suggests that Masked Shrews (*Sorex cinereus*) on Bon Portage Island have been isolated possibly since the last ice age, 10 000 years ago. If voles on Bon Portage Island have been similarly isolated, the population may be inbred, resulting in a high prevalence of recessive homozygous alleles.

Albinism is rare in wild populations of small mammals. Brown (1965) has shown that the conspicuousness of prey is an important determinant in prey selection by terrestrial predators. Albino mammals are easy to locate against a darker background and would normally be selected against in wild populations. At present, quadrupedal predators of voles are absent from Bon Portage Island, and there is no record that any were ever present. This reduced pre-

dation pressure may account for the high percentage of partial albino voles inhabiting Bon Portage Island. However, there are several visually hunting avian predators (e.g. gulls and Northern Harrier, *Circus cyaneus*) on the island, which somewhat weakens the reduced predation argument and strengthens the inbred argument.

Acknowledgments

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Observations on Maternal Behaviour in Muskoxen, *Ovibos moschatus*, During River Crossing

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Mallory, Frank F. 1995. Observations on maternal behaviour in Muskoxen, *Ovibos moschatus*, during river crossing. Canadian Field-Naturalist 109(2): 264–265.

On two occasions, a female Muskoxen (*Ovibos moschatus*) guided her calf across the Goodsir River (Bathurst Island, Northwest Territories) in full flood, by placing herself on the downstream side of her offspring and encouraging it to swim. Although maternal care behaviours have been documented in this species in relation to predator defence and protection from the elements, this is the first record of maternal behaviour during river crossing.

Key Words: Muskoxen, *Ovibos moschatus*, maternal care, river crossing, Bathurst Island, Northwest Territories.

A herd of approximately 30 Muskoxen (*Ovibos moschatus*) observed in Polar Bear Pass, Bathurst Island, Northwest Territories, Canada, (latitude 75° 45' N; longitude 98° 40' W) on 12 July 1979 was led by a single female accompanied by a calf. For 2 hours, the herd grazed and walked slowly from an upland, beach ridge site to a sedge meadow in the valley of the Goodsir River. The composition of the herd was mixed, containing both sexes and multiple age classes typical of this species (Tener 1965; Gray 1987). On reaching the river, which was in full spring flood, the lead female with her calf attempted to enter the deep and fast water. On four occasions, the female turned back and resumed her search for a place to cross further downstream. As the rest of the herd arrived and concentrated along the river edge, they also attempted to find an appropriate crossing site. After approximately 30 min, the animals near the rear of the herd started to mill about and began to return to the sedge meadow. As this occurred, the calf of the lead female slipped and fell into the river and was swept away. The female plunged immediately into the water and swam quickly to the bleating calf. She placed herself on the downstream side of her offspring and guided it to the opposite bank of the river (< 2 min), approximately 100 m below the site of entry. On reaching the opposite side, both animals shook themselves and the female with head held in an upward position, vocalized (bawling) in the direction of the herd. Herd members did not follow, but returned to the meadow. As the herd retreated from the opposite river bank, the female and her calf became increasingly agitated and galloped back and forth along the the rivers edge with the female bellowing. She finally entered the river, again placing herself downstream of the calf and

supported it during the crossing. The water during both crossings was above the shoulders of the female and her calf and the animals were forced to swim most of the distance (40 m). The animals quickly joined the rest of the herd, which had moved approximately 0.25 km from the edge of the river. Similar maternal behaviour associated with river crossing has been reported in Elk (*Cervus elaphus*) by Geist (1982).

Although maternal care behaviours have been well documented in Muskoxen in relation to predator defence (Gray 1987) and protection from the elements (Jingfors 1984), this is the first record of maternal behaviour during river crossing. Muskoxen have been reported to avoid swimming (Gray 1987) but the observations presented here indicate that Muskoxen are good swimmers and female Muskoxen support calves when crossing fast flowing rivers by placing themselves on the downstream side of their offspring. In this instance, the benefits of remaining with the herd apparently outweighed the risk associated with re-crossing the river in full flood. The herd was not seen crossing the river during the remainder of the summer.

These observations support the conclusion of Gray (1987) that during the summer adult female Muskoxen with calves can occupy the position of herd leader, defined as the individual that is followed by the herd and selects the direction of movement. However, the results indicate that leadership fidelity is not permanent in this species and can change quickly if individuals in the herd perceive the risk of following to be too great.

Acknowledgments

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News and Comment

Addendum: *The Canadian Field-Naturalist* 108(4)

Cody, William J. 1994. The flora of the Yukon Territory: Additions, range extensions and comments. Canadian Field-Natualist 108(4): 428-476.

On page 468 a chromosome number of $2n = 24$ was reported for *Synthris borealis* based on seeds grown from a specimen collected by J. A. Calder (34014) but unfortunately the location of the collection was omitted: District of Mackenzie, Northwest Territories, Richardson Mts., on Yukon-Mackenzie border, 67°33'N, 136°12'W, 8 July 1962 (DAO).

WILLIAM J. CODY

Recovery of Nationally Endangered Wildlife in Canada (RENEW)

Two additional reports are now avaiable in this series (see *The Canadian Field-Natualist* 109(1): 124).

National Recovery Plan for the Harlequin Duck in Eastern North America. RENEW Report Number 12. March 1995

National Recovery Plan for the Burrowing Owl. RENEW Report Number 13. April 1995.

Available from:
Recovery of National Endangered Wildlife, Ottawa, Ontario K1A 0H3

Heritage Riverscapes: Spring 1995

Heritage Riverscapes, the newsletter of the Canadian Heritage Rivers Board, Spring 1995, contains an account of Canada's first national River Heritage Conference held in Peterborough, Ontario, on 28-30 October 1994 which celebrated the tenth anniversary of the establishment in the Canadian Heritage Rivers System (CHRS).

There are now 28 rivers accepted or nominated in this program, totalling more than 6000 kilometres. The CHRS promotes and encourages ecotourism initiatives, encourages a philosophy of river and watershed conservation, and community involvement in conservation and tourism.

The first book on Canadian Heritage Rivers: *Voyages: Canada's Heritage Rivers* Edited by Lynn E. Noel with maps and illustrations by Hap Wilson, produced by QLF/Atlantic Centre for the Environment has been published by Breakwater, 100 water Street, P. O. Box 2188, St. John's, Newfoundland A1C 6E6 at $34.95 soft cover, $49.95 hard cover + 7% GST to Canadian orders (shipping and handling for Breakwater orders only: Canada $3.50 for first book and $1.00 for each additional. International $6.00 for first book, $2.00 for each additional). [Available in Canada outside Newfoundland from General Distribution Services, Inc. 30 Lesmill Road, Don Mills, Ontario M3B 2T6 and in the United States from General Distribution Services, Inc. 85 River Dock Drive #202, Buffalo, New York 14207.]

Additional information on CHRS is available on request.

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Global Biodiversity/ La biodiversite mondiale

Global Biodiversity Volume 5, Number 1, pages 1-48, Summer 1995, contains the following - PAPERS: Marine biodiversity: Who benefits, who pays? (Paul Spencer Sochaczewski); UNEP's contributions to biodiversity management (UNEP [United Nations Environmental Program]); Diatoms of the Canadian arctic sea ice (Michel Poulin); In memory of Gerald Durrell: Naturalist, conservationist, author and friend of animals (Suzanne Adamkowski); Canadian biodiversity successes and initiatives;

Diverse quotations; Threespine stickleback diversity: Revealing the origins of biodiversity and speciation (Laura M. Nagel); VIEWS: Legislative update: Endangerd Species Act is under serious attack (Heather L. Weiner); Species on ice (Gregory Benford); NEWS: Biodiversity News: Cyberdiversity: biodiversity and the internet; Biodiversity Meetings; REVIEWS: Book and periodical niche; PORTRAIT OF BIODIVERSITY: Water bear (phylum Tardigrada); and THE LAST WORD: Preserving our natural diversity (Alan R. Emery).

Global Biodiversity (formerly *Canadian Biodiversity*) is published quarterly by the Canadian Museum of Nature and is available in both English and in French editions (the latter as *La biodiverite mondiale*). Annual Subscriptions are $26.75 for individuals and 53.50 for institutions in Canada. $25 U.S. for individuals and $50 U.S. for institutions in the United States and other developed countries, and $10 for individuals and $15 for institutions in developing countries.

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The Ottawa Field-Naturalists' Club 1994 Awards

The 1994 awards were presented at the annual Soirée held at the Unitarian Church in Ottawa on 28 April 1995 with President Frank Pope presiding over the proceedings. These awards are given to recognize and encourage contributions towards club goals by individual members and relevant organizations.

Each of the presidents of the Macoun Field Club (for Ottawa area school age naturalists, grades 7 to 13 and co-sponsored by The Ottawa Field-Naturalists Club and the Canadian Museum of Nature [formerly the National Museum of Natural Sciences, National Museum of Canada] since 1948) Matthew Godsoe (Juniors), Karl Grenke (Intermediates), and Roger Gaertner (Seniors) spoke of last years' activities of their groups and all praised leaders Rob Lee and Mary Stewart for their help. Macoun Field Club members were responsible for an array of natural history exhibits at the Soirée and judges Betty Marwood and Glenneth Anderson awarded a First to William Godsoe (fossils), Second to Pascal Lussier (Butternut Canker) and Third to Matthew Godsoe (Lynx) with an honourable mention to Katherine Kitching (analysis of seed germination in Purple Loosestrife). The Baldwin Memorial Scholarship went to Roger Gaertner, outgoing president.

The Awards Committee expressed its appreciation to retiring members Dan Brunton and Fran Goodspeed for their valuable work on the Committee over several years.

Because The Ottawa Field-Naturalists' Club has maintained its full complement of twenty-five Honorary Members, there were no additions confirmed. Also, as there was no recommendation for the Anne Hanes Natural History Award this year.

1994 Conservation Award (Member) — Ian Huggett

Repeat recipients of OFNC awards are uncommon but there are several members who have so distinguished themselves in a particular area through their continuing commitment to Club objectives. It is his record of continuing commitment to, and action in, conservation in the National Capital area which demands that Ian Huggett be added to this select group. Ian's leadership in mobilizing the citizens of Aylmer to protect the pine forest area of Wychwood led to the establishment of the first ecological reserve in the municipality. For that achievement he was awarded the 1992 OFNC Conservation Award. Not one to rest on past laurels, however, Ian continued to raise public awareness of conservation issues in the Outaouais through his newspaper column. As Director of the environmental activist organization *Ecowatch*, he has been directly influential in a number of conservation issues, including improving ecological aspects of the first Aylmer city Official Plan and in minimizing inappropriate development on the remaining natural lands and water of Aylmer and area.

He has been particularly active lately in promoting the protection of the ecologically sensitive Ottawa River floodplain and the inter-provincial effort to prevent the damage to Deschenes Rapids implied by a hydro-electric development proposal. Ironically, his most recent conservation success was as part of a broadly-based community effort to maintain the ecological integrity of the Wychwood pine woods which was being again threatened despite their conservation status.

If a vigilant public is the price of democracy, Ian Huggett must indeed be one of our foremost democrats. He continues to demonstrate how truly effective a motivated citizen can be.

1994 Conservation Award (Non-member) — The Goulbourn Environmental Advisory Committee

Once again, the OFNC honours a group of Citizens whose local actions have benefited the natural environment of an area long favoured by the Club. In this case we are recognizing the successful effort of a group of dedicated local citizens in converting the abandoned sewage lagoons at Richmond into a wetland conservation area. The Goulbourn Environmental Advisory Committee successfully brought together a variety of public and private conservation and environmental management concerns. With the active encouragement of Goulbourn Council (after considerable constructive lobbying), these individuals and organizations combined forces to create the Richmond Conservation Area in 1993. A year later with the parking lot in place, informal trails identified and regenerating vegetation well established, the lagoons have taken on a very different look — to say nothing of smell!

Clearly, the Richmond Conservation Area will never again be the haven for the hordes of migrating shorebirds that the polluted waters of the old sewage lagoons attracted. As the newly establishing freshwater marsh matures, however, a increasing variety of resident water birds will take up the cattails and shallows of the several ponds here. These represent new opportunities for native wildlife in areas that previously offered little to them. They also present recreational and educational opportunities to local and regional residents and naturalists alike.

Accordingly the 1994 Conservation Award for non-Club individuals is happily granted to the Goulbourn Environmental Advisory Committee.

Member of the Year — Tony Beck

The reasons for Tony's nomination are many. He has served, not just in the past year but throughout the years since he joined the Club, as an invaluable member of The Ottawa Field-Naturalists' Club. His enthusiasm, energy, and generosity have provided an immeasurable service to the Club.

In the past Tony has helped out in a variety of ways including: The Seedathon, the Birds Records Subcommittee, Photo-duplicate custodian, chair of the Bird Committee. Each year sees Tony involved with the Club in a greater capacity. In 1994, as well as continuing his participation in other aspects of the Club, he led a number of bird walks and coordinated field trips.

And last, but perhaps most importantly, are Tony's personal attributes. He is friendly, never condescending; his personal touch comes though in his ability to make people feel at ease, and in the time he takes to help them to understand what they see and to become involved in a range of Club activities.

1994 George McGee Service Award — Ron Bedford

Fourteen years as Chairman of any committee would almost be sufficient grounds for receiving a Service Award, but to chair a committee as important as the Publications Committee for that length of time is a specially deserving achievement. The publication of *The Canadian Field-Naturalist* and *Trail & Landscape* has proceeded methodically and effectively during that time, largely due to the leadership qualities of Ron Bedford.

Ron has guided the Publications Committee with intelligence, steadiness and humour. The Club's Publications Policy has been kept up-to-date largely due to his efforts. Those who heard his presentation on the publications of the Club at the 1994 Annual Meeting will attest to the complete grasp he has of the function of his committee.

However, in noting his work on the Publications Committee we should not underestimate his contributions in other areas. During this period Ron has been a faithful council member where his steadiness and wise input have been of immeasurable value. In addition, the guidance he has shown in many hours of field trips will be remembered by novice and experienced naturalists alike. It is to be hoped that this recognition will encourage him to continue this effective work.

BILL ARTHURS

Chair, Awards Committee, The Ottawa Field-Naturalists' Club

President's Prize, 1994 — Bill Gummer

At the last meeting of the 1994 Council of The Ottawa Field-Naturalists' Club, Bill Gummer told us he had decided not to stand for the 1995 Council. This completed 15 years of service on the Council. Having worked with him over those years, I have come to admire Bill as a person and for his outstanding contribution to the Club. I have, therefore, taken this opportunity to recognize Bill's contributions by awarding him the President's Prize for 1994.

Perusing our records, I note that Bill joined the OFNC IN 1971. He appears on the Council in 1980. For the three years from 1981 to 1983 he was Corresponding Secretary. He was Vice-President for the next two years and President in 1986, 1987, and 1988. In 1989 and 1990 we find him Chairman of the Awards Committee and in 1992 and 1993 Chairman of the Nominating Committee. Since his presidency, Bill has been a member of the Publications Committee. In 1993, while the Editor of *Trail & Landscape* was on sabbatical leave, Bill added the duties of Editor to his regular duties as Associate Editor. Bill was awarded the George McGee Service Award for 1991.

Lest I leave the impression that Bill is dropping out, let me hasten to add that he remains on the Publications Committee, Associate Editor of *Trail & Landscape*, and a member of the ad hoc committee charged with reviewing the Club's equity.

Since 1991, Bill has made his presence felt on the Council as a "corporate memory", backed up by an index of Council motions he has developed over the years. He took the initiative on a lagging revision of the Constitution and By-Laws and steered it through to a successful conclusion. Bill takes an interest in the effective operation of the Club and was instrumental in producing updated terms of reference for all officers and committees. He encouraged the Council to staff committees and set committee goals and agendas early each new year. These are not glamorous accomplishments but they are vital to the effective operation of the Club.

Bill also has artistic talent. It is regularly evident at annual Soirées where his nature photographs capture subjects in an artistic setting. Furthermore, you may recall his piano playing at the Soirée. Bill is an accomplished pianist and performs regularly. Numerous articles in *Trail & Landscape* are evidence of his writing ability. Bill has also written and published two books. The first is based upon his canoeing experience, which is extensive since, as a professional geologist, he has travelled by canoe over much of Canada. The second is about Stony Swamp, an area he knows like the back of his hand. Bill is also a good naturalist who has given many talks and led many excursions. His travels have taken him to the far north of Canada. At home, his garden is a candidate for an article in a gardening magazine. When visiting Bill, I always look into his back yard.

To sum up, it is an honour for me to present the 1994 President's Prize to Bill Gummer.

FRANK POPE

President, The Ottawa Field-Naturalists' Club

Editor's Report for Volume 108 (1994) of *The Canadian Field-Naturalist*

Eighty-seven reseach, observation, major comment, or tribute manuscripts were submitted to *The Canadian Field-Naturalist* in 1994. Issue mailing dates for issues in volume 108 were: (1) 17 November 1994, (2) 28 November 1994, (3) 17 February 1995, and (4) 15 May 1995. Volume 108 totalled 546 pages, the largest single issue (4) was 156 pages. The number of articles and notes is summarized in Table 1 by topic, the totals for Book Reviews and New Titles in Table 2, and the distribution of published pages among issues in Table 3.

M.O.M. Printers, Ottawa, set and printed the journal and special thanks are due Emile Holst and Eddie Finnigan and their staff. Wanda J. Cook proof-read the galleys for the volume. Mickey Narraway remained on call for any additional assistance to the Editor. Bill Cody continued as Business Manager, assisted by Lois Cody. Bill also oversaw the compilation, and proof-read and edited the Index for volume 108 which was painstakingly prepared by Leslie Cody. Wilson Eedy continued as Book Review Editor and compiled the lists of New Titles.

Robert Anderson (Canadian Museum of Nature, Ottawa), Warren Ballard (Wildlife Research Unit, Faculty of Forestry Research, University of New Brunswick, Fredericton, New Brunswick), C. D. Bird (Erskine, Alberta), R. R. Campbell (Canadian Wildlife Service, Ottawa), B. W. Coad (Canadian Museum of Nature, Ottawa), A. J. Erskine (Canadian Wildlife Service, Sackville, New Brunswick), W. E. Godfrey (Canadian Musuem of Nature), D. Laubitz (Canadian Museum of Nature), and W. O. Pruitt, Jr. (University of Manitoba, Winnipeg) continued to serve as Associate Editors in 1994. George La Roi (University of Alberta, Edmonton, Alberta) continued as Coordinator of the Biological Flora of Canada series.

TABLE 1. Number of articles and notes published in *The Canadian Field-Naturalist* Volume 108 (1994) by major field of study.

Subject	Articles	Notes	Total
Mammals	12	22	34
Birds	12	11	23
Amphibians and reptiles	1	2	3
Fish	3	2	5
Invertebrates	5	1	6
Plants	6	3	9
Other	3*	0	3*
Totals	42*	41	83*

*includes one snow ecology article and two tributes (to Lousise de Kiriline Lawrence and to John Steuart Erskine) in News and Comment sections.

TABLE 3. Number of pages published in *The Canadian Field-Naturalist* Volume 108 (1994) by section (number of manuscripts in parenthesis).

Issue number:	- 1 -	- 2 -	- 3 -	- 4 -	Total
Articles	71(10)	84(10)	90(15)	86 (4)	331 (39)
Notes	24(11)	19(10)	16 (9)	24(11)	83 (41)
News and Comment	20(11)	16 (8)	1 (2)	1 (1)	41 (22)
Book Reviews*	19(19)	12(14)	13(15)	20(25)	64 (73)
Index	– –	– –	– –	24 (1)	24 (1)
Advice to Contributors	1 (1)	1 (1)	0 (0)	1 (1)	3 (3)
Total pages:	138	132	120	156	546

*Total pages for book review section include both reviews and new titles listings but parenthesis figures include only the number of reviews.

The following reviewers provided additional evaluations of one or more manuscripts either submitted or returned in 1994: C. Davison Ankney (Department of Zoology, University of Western Ontario, London, Ontario), Richard Arthur (Insitute Maurice Lamontage, Department of Fisheries and Oceans, Mont Joli, Quebec), Ursula Banasch (Canadian Wildlife Service, Edmonton, Alberta), J. S. Bleakney (Acadia University, Wolfville, Nova Scotia), Annamarie L. Beckel (Woodruff, Wisconsin), David M. Bird (MacDonald Campus, McGill University, Ste. Anne de Bellevue, Quebec), Eugene Burreson (Virginia Institute of Marine Science, College of William and Mary Gloucester Point, Virginia), R. Wayne Campbell (B. C. Ministry of Environment, Lands and Parks, Victoria, British Columbia), Lou N. Carbyn (Canadian Wildlife Service, Edmonton, Alberta), Paul M. Catling (Agriculture Canada, Ottawa, Ontario), John Chardine (Canadian Wildlife Service, St. John's, Newfoundland), Jacques Cayouette (Agriculture Canada, Ottawa, Ontario), William J. Cody (Agriculture Canada, Ottawa, Ontario), Pierre Compere (Jardin Botanique de Belgique, Meise, Belgique), William J. Crins (Ministry of Natural Resources, Huntsville, Ontario), Don Cuddy (Ontario Ministry of Natural Resources, Kemptville, Ontario), Darrell Dennis (Canadian Wildlife Service, London, Ontario), D. W. Doidge (Kuujjuaq, Quebec), Michael G. Dolinski (Alberta Agriculture, Food and Rural Development, Edmonton, Alberta), George W. Douglas (British Columbia Conservation Data Centre, Victoria, British Columbia), Daniel Gagnon (Universite du Quebec a Montreal, Montreal, Quebec), Anthony J. Gaston (Canadian Wildlife Service, Hull, Quebec), Frederick F. Gilbert (Natural Resources and Environmental Studies, The University of Northern British Columbia, Prince George, British Columbia), John Gilhen (Nova Scotia Museum, Halifax, Nova Scotia), Patrick T. Gregory (Biology Department, University of Victoria, Victoria, British Columbia), Richard Harington (Canadian Museum of Nature, Ottawa, Ontario), Vernon L. Harms (W. P. Fraser Herbarium, University of Saskatchewan, Saskatoon, Saskachewan), Stuart Hay (Herbier Marie-Victorian, Institut Botanique, Universite de Montreal, Montreal, Quebec), Timothy Heaton (Department of Earth Sciences, University of South Dakota, Vermillion, South Dakota), Thomas Herman (Biology Department, Acadia University, Wolfville, Nova Scotia), Ross D. James (Department of Ornithology, Royal Ontario Museum, Toronto, Ontario), James A. Johnston Ontario Department of Agriculture, New Liskeard, (Ontario), Gordon L. Kirkland, Jr. (Verebrate Museum, Shippenburg University, Shippenburg, Pennsylvania), Murray Lankester (Biology Department, Lakehead University, Thunder Bay, Ontario), H. G. Lumsden (Ontario Ministry of Natural Resources, Maple, Ontario), Wayne C. Leininger (Department of Range Science, Colorado State University, Fort Collins, Colorado), L. David Mech (US Fish & Wildlife Service, N. Central Forest Experiment Station, St. Paul, Minnesota), Gray Merriam (Biology Department, Carleton University, Ottawa, Ontario),

TABLE 2. Number of reviews and new titles published in Book Review section of *The Canadian Field-Naturalist* Volume 108 by topic.

	Reviews	New Titles
Zoology	42	102
Botany	12	45
Environment	12	73
Miscellaneous	7	23
Young Naturalists	0	87
Totals	73	330

Donald F. McAlpine (Natural Sciences Division, New Brunswick Museum, Saint John, New Brunswick), Martin K. McNicholl (Burnaby, British Columbia), W. T. Momot (Department of Biology, Lakehead University, Thunder Bay, Ontario), David Nagorsen (Vertebrate Unit, Royal British Columbia Museum, Victoria, British Columbia), Joseph S. Nelson (Department of Zoology, University of Alberta, Edmonton, Alberta), Alex Peden (Vertebrate Unit, Royal British Columbia Museum, Victoria, British Columbia), Michel Poulin (Canadian Museum of Nature, Ottawa, Ontario), Gilbert Proulx (Alpha Wildlife and Management Limited, Sherwood Park, Alberta), Spencer G. Sealy (Department of Zoology, University of Manitoba, Winnipeg, Manitoba), Michael Raine (Goder Associates Ltd., Calgary, Alberta), Martin Raphael (USDA Forest Service, Pacific Northewest Research Station, Olympia, Washington), Randall Reeves (Okapi Wildlife Associates, Hudson, Quebec), T. E. Reimchen (Queen Charlotte City, British Columbia), Carol Reschke (New York Natural Heritage Program, Latham, New York), A. A. Reznicek (Herbarium, University of Michigan, Ann Arbor, Michigan), Pierre Richard (Department of Fisheries and Oceans, Winnipeg, Manitoba), Frederick W. Schueler (Oxford Station, Ontario), Spencer G. Sealy (Department of Zoology, University of Manitoba, Winnipeg, Manitoba), Norman R. Seymour (Department of Biology, St. Francis Xavier University, Anticonish, Nova Scotia), Kenneth L. Spencer (Exwell Farm, Cornwall, England), Kenneth W. Stewart (Department of Zoology, University of Manitoba, Winnipeg, Manitoba), Ian Stirling (Canadian Wildlife Service, Edmonton, Alberta), Sherman Swanson (Department of Environmental and Resource Sciences, University of Nevada, Reno, Nevada), John B. Theberge (School of Urban & Regional Planning, Faculty of Environmental Studies, University of Waterloo, Waterloo, Ontario), Guillermo Tell (Departamento Ciencias Biologicas, Facultad de Ciencias Exactas y Naturales, Buenos Aires, Argentina), Shaun Thompson (Ontario Ministry of Natural Resources, Kemptville, Ontario), Michelle Wheatley (Department of Zoology, University of Manitoba, Winnipeg, Manitoba), Steve Wendt (Migratory Bird Population Section, Canadian Wildlife Service, Hull, Quebec), Heather Whitler (Wildlife Research Unit, Faculty of Forestry, University of New Brunswick, Fredericton, New Brunswick).

Arch Stewart, Libarian, Canadian Museum of Nature, and members of his staff provided bibliographic help through the year.

My indebtedness to Frank Pope, President of the Ottawa Field-Naturalists' Club, the Club Council and to Chairman Ron Bedford and the Publications Committee of the OFNC continues for their support throughout another year. The Canadian Museum of Nature provided space and facilities for which I am duely grateful. Joyce added encouragement through the year.

FRANCIS R. COOK
Editor

Book-Review Editor's Report for Volume 108 (1994) of *The Canadian Field-Naturalist*

I have lost count of the number of years that I have been Book-review Editor, but I have genuinely enjoyed all of them. The greatest enjoyment is in the people that I have come to know, correspond with, and, even better, occasionally meet. This year has been one of the most stressful and time-constrained periods of my life. It has included starting up foreign offices, major international jobs, and the fact that our Editor has done an amazing job of catching up in the publication timing of *The Canadian Field-Naturalist* issues - each one requiring its new titles and reviews. As a consequence I have had to rely even more on my many faithful reviewers to remind me that they are available and to tell me the books that they wish to review. To all of you, please keep it up. Please do not wait for me to call you. Please remind me if I do get a bit behind in my correspondence.

Statistics I will keep to a minimum. Due to the speed of publication for Volume 108, I believe these are all lower than some of the peak years but they do illustrate some interesting points. Sixty-seven books were sent to reviewers and sixty-three reviews were completed, while seventy-three were published. All this illustrates some consistency. There is an average of about a year from when a book is sent to the reviewer to when the review is received and published. Although only forty-three books were specifically requested, eighty-seven were received. This, and the fact that some came as far as from Australia, illustrates that we have attained a good reputation with the publishers. In Volume 108, we listed 330 new titles. Hopefully all of these were of some value to our readers.

I would like to use a bit of editorial prerogative and comment on something which has become a continuing and increasing concern - Canada Post. I ship or receive several hundred parcels per year. The cost averages \$5 to \$10 per parcel. This is at least 10 to 20 times what it was when I started some 20 or so years ago. In the last month, I know of at least three

parcels (books valued $50 to $75 each) and one first class letter that have gone missing. How many have I not heard of? In each of these cases an empty package has been returned, in damaged condition, marked: "Received in damaged condition". I know that I gave them to the post office undamaged. On complaining, I have been told that Canada Post accepts no responsibility for what happens to a parcel after you give it to them unless you pay an additional $5 to $10 in insurance. In my business, if I provided no better service, I would be out of business. We are a non-profit, voluntarily run, naturalist club. Are there any suggestions to how this can be resolved?

I am a strong advocate of internet. Many reviewers now correspond completely electronically. It is instant, at no cost, and almost always works. I can accommodate uunencoded or attached files of almost any form at <we@geomatics.com>, ftp files at the anonymous address <geomatics.com> (you have to E-mail to tell me it is there), or you can check me out at WWW/URL <http://geomatics.com>. I can also receive messages (but not files) at <wilson @beak.com>. If you have access but do not like to send files, at least send an e-mail note to expect a file will help foil the Canada Post gremlins.

Every year I send a plea for volunteers. I would like to include a plea that past reviewers contact me when interested and do not wait. I do try to keep up, but half my life is spent in somewhat exotic but totally inaccessible parts of the world. I do need, welcome, acknowledge, and could not do without the wonderful help of my many friends and reviewers.

WILSON EEDY, Ph.D.

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Henry Mousley and the Orchids of Southern Québec

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Sabourin, André, and Roger Perreault. 1995. Henry Mousley and the orchids of southern Québec. Canadian Field-Naturalist 109(2): 273–281.

William Henry Mousley was a self-taught naturalist who was born in England in 1865 emigrated to Canada with his family in 1910. His observations on the orchid flora are of particular interest to the botanist. In southern Québec, he found close to 50 taxa of Canadian orchids, and wrote 32 scientific papers on them between 1919 and 1944. His most important contributions included the discovery of a species new to Canada and another one new to Québec, original observations on the roots and reproductive behaviour of certain orchid species, contributions to orchid taxonomy, including analysis of diagnostic characters, and descriptions of four new taxa (forms).

Key Words: William-Henry Mousley, naturalist, orchids, southern Québec.

William Henry Mousley was one of Québec's most eminent naturalists and a true pioneer in the study of our wild orchids (Figure 1). He was born on 17 February 1865 at Taunton, in the county of Somerset, in south-west England. His interest in natural history was kindled at a very young age and which subsequently grew into a passion for birds which lasted his entire lifetime (Ainley 1981). However, Mousley also became interested in botany, especially orchids and ferns, and in entomology, focusing mainly on butterflies.

As a young man Mousley trained as a civil engineer and began his professional career as an agent in his father's railway contracting business. At this time he also met Mary Lake, whom he married in 1885. This union brought forth a dozen children, of which five girls and two boys survived to reach adulthood. Unfortunately, at the turn of the century, the fortunes of the family deteriorated and Mousley barely escaped bankruptcy. In 1910, foreseeing no future in England, the family decided to emigrate to Canada. They established themselves in the Eastern Townships region of Québec, at Hatley, which is situated in the county of Stanstead.

Hatley and its environs, 1910-1924

By contrast to his formal training as a engineer, Mousley was a self-taught naturalist. At the age of 45, Henry Mousley plunged himself into observing nature at Hatley, a place little explored by naturalists. At the beginning, this pastime proved a solace against depression and his having to work away from home for the Ottawa-Toronto Railway (Ainley 1981). The intervening war years, combined with his now fragile health, compelled him to become a full-time naturalist, an occupation which he undertook with a dedication seldom matched.

During these early years Mousley focused more on birds than plants, and between 1911 and 1918 he devoted himself almost entirely to ornithology. He wrote that his first encounters with orchids came as result of his interest in warblers (Parulidae), several species of which are found in the same humid coniferous or mixed forests as the vast majority of our native orchids. This habitat is encountered frequently in the undulating terrain of Stanstead county, which also favours the formation of marshes and peat-bogs. On one particularly memorable fine spring day in 1918, while following the feeding behaviour of a Cape May Warbler (*Dendroica tigrina*) at the edge of a cedar swamp, he came upon his first Calypso (*Calypso bulbosa*), a small rare orchid of southern Québec (Figure 2). The morning of 15 May would remain indelibly imprinted in his memory for the rest of his life.

At this time the Mousley family lived approximately 2.5 km south of the village of Hatley, and he would discover just six species of orchids while living there. In 1917, however, the family moved to a house close to a marshy area approximately 1.5 km north of the village. Here, he quickly added 12 species to his growing list of wild orchids. His most important discovery was of a peat-bog which sheltered two rare species, Arethusa (*Arethusa bulbosa*) and the Queen (Showy) Lady's-slipper (*Cypripedium reginae*).

In 1919, after the spring migration of birds, Mousley decided to discontinue his field work in ornithology until the fall, and to occupy himself solely with the ferns and orchids. Benefitting from a particularly hot and humid summer, conditions which favour orchid growth, he discovered no less than 12 additional species. By the end of the year he had discovered a total of thirty orchids (including species, hybrids and varieties) in a restricted area of 6.5 square kilometres around Hatley. This was fully one third of all the wild orchids known from eastern North America at that time. In his

FIGURE 1. William Henry Mousley, 1865 (Taunton, England) — 1949 (Montréal, Canada).

FIGURE 2. *Calypso bulbosa*. Taken from Mousley's herbarium by the Canadian Geological Survey.

notes he referred to this time as "an orgy of orchids".

The next year, 1920, Mousley, an ambitious and competitive man by nature, set out to challenge the north-eastern locality record of 33 orchids, at that time held by Fairlee, Vermont (Mousley 1920b). He did find three other species, namely, Small Round-leaved Orchid (*Amerorchis rotundifolia*), Hooker's Orchid (*Platanthera hookeri*) and Rose Pogonia (*Pogonia ophioglossoides*). However, only the Hooker's Orchid was found in the immediate area, the other two species being found at Beebe and in a peat-bog at Waterville. In the following years Mousley attempted to locate eight new possible species of orchid, but he knew well that this would be a difficult task, especially for Ram's Head Lady's-slipper (*Cypripedium arietinum*) and Broad-leaved Helleborine (*Epipactis helleborine*). The *Epipactis* is found abundantly nowadays, but at that time this european plant was unknown in the region. Mousley was away during most of the summer of 1921, but the following summer he encountered three new species in the great marsh at Beebe, Menzies' Rattlesnake Plantain (*Goodyera oblongifolia*), Small Green Wood Orchid (*Platanthera clavellata*) and Ragged Fringed-orchid (*Platanthera lacera*). At this single location he was to find 18 orchid species altogether.

In 1923, Mousley discovered four additional species: Downy Rattlesnake Plantain (*Goodyera pubescens*), White Fringed-orchid (*Platanthera blephariglottis*), a hybrid (*Platanthera x media*) and Nodding Ladies'-tresses (*Spiranthes casei*). By the end of 1923 he had succeeded in reaching the incredible total of 40 taxa (species, varieties and hybrids) of orchids in the region of Hatley, as

TABLE 1. Alphabetical list of orchids observed by H. Mousley in the region of Hatley between Lake Memphremagog and the Coaticook River, from 1911 to 1924 (the names in parenthesis are those of Mousley).

Amerorchis rotundifolia (*Orchis rotundifolia*)
Arethusa bulbosa
Calopogon tuberosus
Calypso bulbosa
Coeloglossum viride var. *virescens* (*Habenaria bracteata*)
Corallorhiza maculata
Corallorhiza trifida
Cypripedium acaule
Cypripedium calceolus var. *parviflorum* (*C. parviflorum*)
Cypripedium calceolus var. *pubescens* (*C. parviflorum* var. *pubescens*)
Cypripedium reginae (*C. hirsutum*)
Galearis spectabilis (*Orchis spectabilis*)
Goodyera oblongifolia (*Epipactis decipiens*)
Goodyera pubescens (*Epipactis pubescens*)
Goodyera repens var. *ophioides* (*Epipactis repens* var. *ophioides*)
Goodyera tesselata (*Epipactis tesselata*)
Liparis loeselii
Listera convallarioides
Listera cordata
Malaxis monophyllos var. *brachypoda* (*Microstylis monophyllos*)
Malaxis unifolia (*Microstylis unifolia*)
Platanthera blephariglottis (*Habenaria blephariglottis*)
Platanthera clavellata (*Habenaria clavellata*)
Platanthera dilatata (*Habenaria dilatata*)
Platanthera grandiflora (*Habenaria fimbriata*)
Platanthera hookeri (*Habenaria hookeri*)
Platanthera hyperborea (*Habenaria hyperborea*)
Platanthera lacera (*Habenaria lacera*)
Platanthera macrophylla (*Habenaria macrophylla*)
Platanthera obtusata (*Habenaria obtusata*)
Platanthera orbiculata (*Habenaria orbiculata*)
Platanthera psycodes (*Habenaria psycodes*)
Platanthera x *andrewsii* (hybrid between *P. lacera* and *P. psycodes*; *Habenaria andrewsii*)
Platanthera x *media* (hybrid betwen *P. dilatata* and *P. hyperborea*; *H. dilatata* var. *media*)
Pogonia ophioglossoides
Spiranthes casei (reported as *S. cernua* var. *ochroleuca*; *S. vernalis*)
Spiranthes cernua
Spiranthes lacera (reported as *S. gracilis*)
Spiranthes lucida
Spiranthes romanzoffiana

shown in Table 1 (Mousley 1919, 1920, 1922, 1924a, 1925b).

In 1922 and 1923, Mousley attempted to introduce colonies of four orchids in the region of Hatley, namely Puttyroot (*Aplectrum hyemale*), Sparrow's Egg Lady's-slipper (*Cypripedium passerinum*), Broad-leaved Helleborine (*Epipactis helleborine*) and Crane-Fly Orchid (*Tipularia discolor*). In 1925, he reluctantly admitted failure, with the exception of *Aplectrum*, whose root had survived. Except for *Epipactis* these results were of no surprise. Both the *Aplectrum* and *Cypripedium* were very rare in Canada and *Tipularia discolor* was confined to western Canada. We know today that orchids rarely transplant well and, except in rare and special circumstances, is not something that should be encouraged or attempted.

Montreal and its surroundings, 1924-1949

In September 1924 the family moved to Montreal so that the youngest child could attend McGill University. The change from life in the country to that of a metropolis proved difficult for Mousley, but he made new friends through contact with a group of ornithologists from The Province of Quebec Society for the Protection of Birds (PQSPB). In 1926, he was offered a post with the Emma Shearer Wood Library of McGill University. The library specialized in ornithology and zoology, but was poorly funded; nevertheless, even though he was underpaid as a result, Mousley was to spend a dozen years working there.

Once, upon alighting from a train in Montreal, Mousley met one of his correspondents, Louis M. Terrill, a botanist from St. Lambert, who was to become his friend and principal fieldwork compan-

ion. Terrill himself observed the birds of Mount Royal and had studied the *Epipactis helleborine* [syn. *E. (Amesia) latifolia*], which had earlier been discovered on Mount Royal in 1892, and which at the time was the only spot in Québec where this European orchid had been found. This plant quickly spread over the entire mountain and it was soon to bloom elsewhere on the island of Montreal. Mousley made a detailed study of the orchid and later published his findings, in 1927. Therein, he described for the first time three forms, of which one is entirely white (*albino*). Moreover, on 18 July 1925, he found three plants on Mount Royal which were characterized by their dark-red to purple-brown flowers. Mousley sent specimens to experts in Europe, who confirmed his hypothesis that it was a new species for North America. *Epipactis rubiginosa* is now known under the name of *Epipactis atrorubens*, but Mousley's specimen at the Marie-Victorin Herbarium has since been reclassified as *Epipactis helleborine* (Catling 1983).

Mousley continued to botanize farther afield in the Montreal region, oftentimes with Terrill, with the areas of St. Lambert, Laval, Terrebonne, Oka and St. Hippolyte being most frequently visited. He visited many other towns less frequently, such as Como (Hudson), where he saw for the first time the Tubercled Orchid (*Platanthera flava*), in 1926. Terrill often commented upon his companion's enthusiasm; for example, Terrill reported that whenever Mousley would make a new discovery, he would excitedly exclaim, "I've got it, I've got it!".

As mentioned earlier, Mousley had been searching in vain around Hatley for the Ram's Head Lady's-slipper (*Cypripedium arietinum*). Despondent about this lack of success he wrote, in 1923, to Brother Marie-Victorin, requesting to be informed about the location of this plant in Québec. Mousley communicated with him often between 1920 and 1924, and they frequently searched for plants together. Then, on 3 June 1927, Terrill and Mousley discovered two populations of *C. arietinum* in Chambly (Mousley 1928). According to the notes of Brother Marie-Victorin they found another population on 11 June at St. Francois (Laval), near Terrebonne, growing beside the reddish Striped Coral-root (*Corallorhiza striata*) (Figure 3). The species has since disappeared from this locality.

The same fate was to befall three of the 11 orchids observed by Mousley at Oka, namely *Amerorchis rotundifolia, Aplectrum hyemale* and *Arethusa bulbosa* (Mousley, 1928, 1932a and 1932b). *Aplectrum*, for example, discovered for the first time at Oka by Father Louis-Marie in 1929, was observed by Mousley and Terrill in an oak grove on 1 October 1930 and 3 June 1931. At that time, Oka was the only known locality for this species in Québec. For reasons unknown *Aplectrum* has never been relocated in Oka, although it has since been discovered at two locations in the Monteregian area of Québec (Lavoie 1994). In the case of *Arethusa* and *Amerorchis* the loss of these species at Oka can be ascribed to the draining of the peat-bogs for agricultural purposes. Unfortunately, another rare orchid also appears to have disappeared from the Ste. Dorothée area of Laval. This is the small Southern Twayblade (*Listera australis*), which Mousley discovered for the first time in Québec, on 27 June 1940 (Mousley 1940). In a small peat-bog at this location, he observed three other orchids, Grass Pink (*Calopogon tuberosus*), White Fringed-orchid (*Platanthera blephariglottis*) and Rose Pogonia (*Pogonia ophioglossoides*).

On 26 August 1941, Mousley found another rare orchid at Ste. Dorothée, *Spiranthes casei* (reported as *S. vernalis*, *S. casei* was recognized as a distinct species by Catling and Cruise in 1974). In 1941 and 1942 Mousley published articles on this new Canadian species, which he had found in Hatley as early as 1923, and which is distinguished from the other *Spiranthes* by its yellowish flowers set along in a single row (Figure 4).

Observations on orchid propagation

The research undertaken by Mousley did not limit itself to just collecting and photographing orchids - he also studied certain species in depth. He was particularly fascinated by the underground development and vegetative propagation of Calypso (*Calypso bulbosa*), Helleborine (*Epipactis helleborine*), Green Adder's-mouth (*Malaxis unifolia*), Case's Ladies'-tresses (*Spiranthes casei*), Nodding Ladies'-tresses (*Spiranthes cernua*) and Hooded Ladies'-tresses (*Spiranthes romanzoffiana*).

Mousley involved himself in polemics on the Calypso orchid with a specialist, Professor Oakes Ames of Harvard University. The latter claimed that the tuber of Calypso is seldom accompanied by coralloidal rhizomes, whereas Mousley was of the opinion that this phenomenon was often encountered, especially when the species grew on rotting logs or stumps. Moreover, using photographic plates, Mousley traced the vital underground development of this species (Mousley 1924f, 1925a).

Mousley was the first to publish material on the root system of Helleborine (Mousley 1927a). He noted that this species produces, in addition to the two incipient tubers usually found at the base of the new bud, four others. He observed the same thing (here, as many as twelve tubers) for Nodding Ladies'-tresses and Hooded Ladies'-tresses, especially when the plants grow on dry ground (Mousley 1924b, 1924d). He explained this observation as a response by the plant to create extra reserves in times of drought. Concerning Hooded Ladies'-tresses, Mousley was the first to observe and collect an

FIGURE 3. *Corallorhiza striata* and *Cypripedium arietinum*. Photograph taken from Mousley's herbarium specimen by the Geological Survey of Canada.

insect pollinator of this species - the bee *Chlorhalictus smilacini* (Mousley 1924e).

By studying the underground development of Case's Ladies'-tresses, he found that it coincided exactly with that of Hooded Ladies'-tresses, both as regards the stout and fleshy appearance of the tubers with their general tendency to grow downwards, and the production of the new bud in the fall (and not in the spring, as stated by Drummond in 1810). Further, he found that the new bud is attached to the parent plant, as in Hooded and Nodding Ladies'-tresses, with no indication whatsoever of individual buds becoming separate plants, as stated by Drummond (Mousley 1942).

Mousley similarly observed that the propagation of Green Adder's-mouth is accomplished not only by means of its seeds, but also vegetatively by little bulbils. He was not the first to observe this , but he was the first to publish photographic evidence of this phenomenon (Mousley 1924c, 1927b).

FIGURE 4. Upper row: identified as *Spiranthes vernalis* by Mousley, redetermined as *S. casei*. Lower row: *S. cernua* except for the last specimen to the right (*S. romanzoffiana*). Taken by the Montréal Botanical Garden of specimens from the Marie-Victorin Herbarium (MT).

Innovations in orchid taxonomy

Four taxa proposed by Mousley as new varieties or forms, as described below, are still found in the current literature and taxonomy and are now considered at the taxomonic rank of *forma* (Catling 1983).

Amerorchis rotundifolia (Banks) Hultén *f. lineata* (H. Mousley) Hultén was proposed by Mousley under the name *Orchis rotundifolia* Banks var. *lineata*, var. nov. (Mousley 1941a). That year Mousley published, in the National Herbarium, the results of his findings from an examination of 250 specimens of Small Round-leaved Orchid taken from all over Canada and Alaska. The type locality was Elkwater Lake, Cypress Hills, Alberta, 27 June 1932, W.C. McCalla, No. 3843-A (CAN). The specimens have a striped, rather than a spotted, labellum with very rich deep purple bars.

Epipactis helleborine (L.) Crantz *f. monotropoides* (Mousley) Scoggan. Mousley found this orchid growing at Monkland, near Montreal, on 19 August

1925 (type in CAN. No. 116.715). The specimens are characterized by a total absence of chlorophyll, the only colouring consisting of a very pale rose-mauve suffusion in the lower part of the stem and in one flower (Mousley 1927a). He named this new form, *Amesia latifolia* (All.) Nels. and McBride *f. monotropoides*.

Malaxis monophyllos (L.) Swartz var. *monophyllos f. bifolia* Mousley

Malaxis unifolia Michx. *f. bifolia* Mousley

Mousley named the former after he came across literally hundreds of the plants in a damp wood near Terrebonne, north of Montreal, on 27 June 1927. Mousley named the latter from a specimen collected at St. Hippolyte, in the Laurentians north of Montreal, on 8 July 1927. In both species, the additional leaf is situated above the normal one, rarely below it (Mousley 1927b, 1927c, 1928, 1929b).

In 1925, Mousley published an article on the varieties of *Corallorhiza maculata*. He described three varieties (now forms of the typical variety): var. *flavida*, with lemon-yellow flowers and an unspotted white lip which he recorded from north-east of Toronto; var. *punicea*, from Hatley, which has a pink shade, the scape and fruit having no trace of brown; var. *intermedia*, also from Hatley, which is a form halfway between the two. At the time no intensive work had been done with regard to the distribution of these varieties in Canada.

Finally, Mousley wrote an article on two related species, *Habenaria orbiculata* and *H. macrophylla* (Mousley 1934). He pointed out that it is misleading when text books describe *H. macrophylla* as being larger in all its parts than *H. orbiculata*. He placed emphasis on the fact that one cannot rely upon the diameter of the leaves but, rather, should compute the length of the spur. This is seldom longer than 25 mm in the case of *H. orbiculata*, while it is between 30 and 40 mm in the case of *H. macrophylla*. These differences have now been confirmed by the recent scientific studies of Reddoch and Reddoch (1993), who have maintained the treatment of the two taxa as distinct species. Mousley also showed in his article a photographic plate of a specimen from St. Hippolyte (8 July 1929) which had a third leaf of a fair size. For unknown reasons, this new form (*trifolia*) is not retained by modern authors (Luer 1975; Scoggan 1978, Catling 1983).

In 1943, Mousley bequeathed his herbarium, comprising approximately 500 sheets, to l'Institut Botanique de l'Universite de Montreal (Marie-Victorin Herbarium (MT)); he also donated many important books and a collection of photographs. At the age of 79 he published his last article on orchids in the May/June 1944 issue of The Canadian Field-Naturalist. It dealt with abnormalities in orchids and an example shows a regressive specimen of *Cypripedium calceolus* var. *pubescens*, whose labellum is replaced by a petal similar to the other two.

Mousley, despite his old age, continued to keep up his interest in orchids. On 17 January 1948, on the eve of his 84th birthday, he wrote to Ernest Rouleau, then curator of the Marie-Victorin Herbarium. In his letter he draws Rouleau's attention to a form of a variety of Green Adder's-mouth (*Malaxis unifolia*), which bore abnormally long leaves. By this time his handwriting was poor and he apologizes for forgetting the curator's name.

Following a recurring illness, William Henry Mousley passed away on 22 September 1949 at the Montreal General Hospital. His death occurred exactly 25 years after he came to Montreal and was reported in the The Montreal Star (1949) and The Canadian Field-Naturalist (Terrill 1950).

Conclusion

Henry Mousley left a legacy of 131 scientific papers, published in Canada, the U.S. and the U.K., of which 32 concerned orchids. In addition, he had been an active member of many scientific societies.

As a field naturalist Mousley made a major contribution to botany in Québec, particularly to our knowledge of the orchid flora. He collected and photographed almost all the species of orchids of southern Québec, and he described aspects of their morphology, ecology and distribution in his publications. An important historical aspect of his observations in the Montreal area is that they bear witness to the significant decline in orchids in this region. His work on reproduction and taxonomy was more than that of a naturalist, it was that of an orchid specialist. His numerous publications are a valuable contribution to the field.

We leave the final word to Mousley. A quotation he used as an introduction to an article on the Calypso orchid that was published in 1925 appropriately sums up his passion for orchids:

> I have found an orchid:
> "What is that ?" you say.
> *T'is a proof that miracles*
> *happen every day*

Acknowledgments

We thank Stuart Hay, assistant conservator of the Herbarium Marie-Victorin, for suggesting this work, for furnishing material on Mousley and for providing corrections to the text; Normand Fleury of the "Médiatheque du Jardin Botanique de Montréal", who supplied the photographs of orchids for this article; Marianne Gosztonyi-Ainley, Concordia University, who so kindly supplied both the photograph of Mousley and material on his life history; Luc Brouillet, curator at the Marie-Victorin Herbarium who corrected the french text; Edgar Martins, mechanical engineer, who translated the text from the french and Robert Barnhurst, naturalist

and metallurgical engineer, who provided final revisions.

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Book Reviews

ZOOLOGY

Lake, River and Sea-Run Fishes of Canada

By Frederick H. Wooding. 1994. Harbour Publishing, Madeira Park, British Columbia. $32.95.

This book is the most recent edition of *The Angler's Book of Canadian Fishes* (1959) and *The Book of Canadian Fishes* (1973). It comprises a "Foreword" of 4 pages by J. S. Nelson, an "Introduction" of 10 pages covering some general aspects of biology and structure, a section on "Canada's Aquatic Heritage" by R. R. Campbell of 11 pages which treats threatened fishes, 7 pages of references, an index of 11 pages, and the bulk of the text at 239 pages.

The main text is given over to descriptions of selected families and species of freshwater fishes, for a total of 87 named species in the table of contents plus comments on 7 families in general. The salmon family deals with 21 species (covering almost half the species text at 100 pages), the carp family 13 species (16 pages), the sunfish family 10 species (18 pages), the catfish family 8 species (10 pages), and the remainder having 5 or less species listed. The species coverage is of the more prominent, larger species and those of commercial or sporting importance, with some other groups. Coverage is not exhaustive for this fauna as should be expected from a popular guide. Illustrations comprise 36 small colour plates and 18 line drawings.

As a general guide to Canadian freshwater fishes, this book is an easily readable account with anecdote and fact nicely mixed. Having said this I must draw attention to various items I found disconcerting. These include errors which should have been caught by the editors such as the misspelling of *Ammocryupta*, the margined madtom's scientific name being given as *Gasterosteus insignis*, and the contents listing a Class Actinopterygii for two orders but not the others which fall in this category nor indeed any indication of those orders which do not (taxonomy is confusing enough for the layperson without adding to it).

The colour plates are small and generally inaccurate. The line drawings are not distinctive enough; e.g., on page 179 there are six fish with four names — which name applies to which fish? Factual errors sneak in occasionally — tuna are not warm-blooded in the same sense that we are, the story is fascinating but not told here; eels do have scales, albeit small ones; there are three, not two, Canadian hagfish species.

A number of fish are mentioned which are not Canadian or not freshwater fishes. The tuna is a case in point but acceptable in a general account of biology; but why is the Californian grunion given equal billing with a Canadian relative and why mention the Asiatic masu and amago? The reference list is eclectic and coverage is not a full entry to the Canadian fish literature. It ill behooves me to quote omissions as there are too many colleagues neglected. Some references are incompletely cited making them difficult to locate.

I believe there is more room for Canadian information and anecdote, focusing perhaps on the lesser known species as the sport fishes have been well covered in numerous works. I would even advocate a book on Canadian fishes not drawn from the species composition (too many to cover in a popular guide) but from topics enlivened by Canadian examples. Many interesting features of fish biology can be developed as an entertaining and informative read on behaviour, evolution, adaptations, reproduction, migration, physiology, age and growth, experimental animals, unusual products, fisheries and their decline, and so on.

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Ontario Birds at Risk: Status and Conservation Needs

By J. W. Austin, M. D. Caman and R. D. James. Federation of Ontario Naturalists, Don Mills, Ontario. 165 pp., illus. $10.25.

When I first heard of *Ontario Birds at Risk*, I thought that it was a great idea. As I read the book my high hopes were quickly dampened, each time I read a portion of the book I become a little more disappointed.

Compiling data from *The Atlas of the Breeding Birds of Ontario*, and the *Ontario Rare Breeding Bird Program* was an excellent concept. It is extremely unfortunate that more studies are not made available to the public in an accessible form. Publishing data for the public is most important as it shows volunteers that their efforts have been useful and provides information to those not inclined to delve into the scientific literature and reports.

Beyond the basic idea of identifying species at risk and providing conservation ideas, however, this book is substandard. The first major problem is the species chosen. The rarest breeding birds in the province were selected for coverage, while species that studies at the Long Point Bird Observatory (LPBO) have identified as declining are ignored (see Hussel et al. 1992). These migratory species are in some cases very common summer residents in the province yet their numbers have undergone great declines. It seems to me that we should point out the problems with extremely common species in addition to rare species. Conservation issues are not limited to rare species.

The mix of species is unbelievable. Bald Eagle, Caspian Tern, Tufted Titmouse, Chuck-will's-widow, and American Avocet are a set that have little in common. Suggesting that these species are even worthy of treatment together is questionable. Birds such as Western Kingbird, Snowy Owl, and Peregrine Falcon are agruably only occasional breeders or species on the edge of their range in Ontario. It is really worth devoting energy in Ontario towards the Canvasback when essentially 100% of its breeding range is outside the province and several organizations have dedicated themselves to this species in particular or waterfowl in general?

Many of the data used are questionable while other important data are overlooked. In several accounts breeding locations are missed. Many volunteers who collected data are unfamiliar with the species' breeding biology. I know of people who are looking for Black Terns over open water and Henslow's Sparrows during the day. I can only imagine how many breeding locales for species such as Yellow Rails, King Rails, and other cryptic species have been missed.

The presentation of data for several species needs improvement. Several species are far less plentiful than their maps would suggest. Henslow's Sparrow and Loggerhead Shrikes are far more limited and numbers are plummeting; in recent years you could count them on a couple of hands. Blocking a location does little to indicate the breeding population.

The Conservation Needs section is woefully general. Many accounts suggest further surveys and to report sightings to LPBO or Federation of Ontario Naturalists. Reporting sightings to these organizations seems to have little benefit for most species. Continued surveys are not necessary in many cases. These may provide short-term work for many consultants but they will not necessarily help the species. What we need is on-the-ground action, not number and paper production.

A frequent recommendation is that habitat should be preserved. This is obvious. Unfortunately, saving habitat as a general idea is a long-term proposition, just ask World Wildlife Fund. Priority must be given to saving large tracts of habitat and picking species that have had a solid breeding population in the province. It is unfortunate that what I consider the single most important conservation effort, World Wildlife Funds' Endangered Spaces campaign, has been given little coverage. There needs to be more identification of the most critical habitat and methods to save it. Species such as Acadian Flycatcher are so limited in breeding locations that it would be well worth mentioning the five most vulnerable locations. This would provide specific locations that local groups could work towards preserving.

Consistency within accounts is often substandard. In the King Rail account, Prince Edward County is listed as once harbouring the largest populations of the species. Presqu'ile has hosted breeding pairs only occasionally. Presqu'ile's marshes are singled out for protection to aid the King Rail yet those in Prince Edward county are not.

It is interesting that no bird success stories are mentioned. In the 1970s few or no Wild Turkeys existed in the province. Reintroduction programs have had a profound effect with so many turkeys now that they are a nuisance in some areas. Species such as Eastern Bluebird, Purple Martin, and Wood Duck have all been greatly helped by human intervention. If only governments, naturalists and other organizations could work together more often.

What good can be said for this book? Well, at least some initiative has been taken. It would be worthwhile for every person who has an effect on the environment to use this as a starting point to

understand conservation needs. The price is right, a decent meal cannot be had for the amount. The art work is interesting with the cover photo of the Hooded Warbler being particularly attractive.

This review could go on and on. There are so many comments that I could fill pages. The authors have done a good service by compiling data and forwarding suggestions. Perhaps we should consider this book a starting point. Do not look to this book to solve bird population problems but do buy it to support the cause.

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Cheetahs of the Serengeti Plains

By T. M. Caro. 1994. The University of Chicago Press, Chicago. 478 pp., illus. Cloth U.S. $70; Paper U.S. $26.95.

Few aspects of carnivore ecology are as little known and difficult to study as social behavior. Caro, associate professor in the Center for Population Biology and the Department of Wildlife and Fisheries Biology at the University of California at Davis, has used an intensive 10-year study of the Cheetah to explore and understand the costs and benefits of sociality. The objectives of this book were to: (1) explore the evolutionary causes of social behavior, (2) examine the behavior of Cheetahs from a functional perspective, and (3) provide a synthetic account of the biology of Cheetahs in the wild. The author has met these objectives in a remarkably detailed and comprehensive fashion.

The book is divided into 13 chapters, which cover grouping and cooperative hunting, taxonomy and natural history, an overview of the study area and data collection methods, female reproduction and cub mortality, costs of family life for mothers, benefits of family life for cubs, hunting and grouping in adolescents, mating systems, territoriality and male group size, foraging success and cooperative hunting in male groups, male behavior in coalitions, ecology and evolution, and the conservation of Cheetahs in the wild and captivity. The chapters are followed by 12 appendices which describe in more detail topics including Cheetah home range sizes, ungulate population estimates, hunting success, comparative dietary analyses, subspeciation, and comparative life history parameters among felid species. An exhaustive bibliography is followed by a comprehensive and highly useful index.

Throughout each chapter are figures and tables which are easy to understand and complement the text well. Numerous illustrations and photographs further improve our understanding of the system studied and accentuate behavioral traits described in the text. I was pleased to find only one typographical error in the entire book.

It is apparent that the author is an expert in behavioral ecology, having compiled, in my opinion, one of the most thorough treatments of social behavior based on intensive field work to date. A complete analysis of each topic covered is thoroughly discussed relative to current theory and supporting literature. Caro's writing style is the perfect blend of scientific and layperson terminology, making this book equally readable for the serious behaviorist or casual reader. Statistics used to support statements made in the text are placed at the end of each chapter, which provided improved flow of material without sacrificing quality of the information. I was impressed with the author's appropriate use of statistical analyses and willingness to acknowledge shortcomings (although relatively few) with the data.

Cheetahs of the Serengeti Plains is destined to become an important reference on social behavior and a classic on felid biology. I recommend this book without reservation to behaviorists, carnivore ecologists, and laypersons alike.

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City Peregrines: A Ten-year Saga of New York City Falcons

By Saul Frank. 1994. Hancock House, Surrey, British Columbia and Blaine, Washington. 313 pp., Illus. $29.95.

What a triumphant story Saul Frank has to tell! After extirpation of the Peregrine Falcon, the fastest bird in diving flight, from the eastern half of North America, reintroduction programs have restored numbers to approach the pre-DDT population levels. The Peregrine Fund extended their release program, which began in the late 1970s, to New York City in 1980 and 1981. New York mayer Ed Koch declared 30 June 1991 as "Peregrine Falcon day."

In 1983, Saul Frank heard of a pair of peregrines nestong on Throgs Neck Suspension Bridge, at eye-level view from his downtown New York City apartment, and another pair on the Verrazano-Narrows bridge. That summer five young peregrines were raised on the two bridges, the first nest success in the metropolitan area since the 1960s, and the first-ever known success on bridges on this continent. He shares 180 prey captures recorded during over 2500 hours of detailed falcon observations, from courtship of the year-round resident adults to the full departure of the young. He is an ardent cyclist; some days he makes his over-40-mile circit by bicycle.

The number of nesting falcon pairs increased steadily until 1993, when nine pairs in the metropolitan area raised 34 young. A number of the parents carried aluminum leg bands that showed their origin from "hack sites" in other cities as far away as Boston.

Saul takes risks when he visits nest ledges on tall bridges, sometimes to provide a nest box to reduce the chance of nestlings falling into the water, or later to assist in banding of the young. One dodge from an attacking parent falcon could be fatal; one peregrine female flew off clutching Saul's hat in her talons. One of the bridge workers was given such a deep gash that sutures were required to close the wound.

When fledglings fell into the water or onto the street, Saul was often part of the rescue team that carried them back to their nest. One fell into a smokestack; the ash-covered youngster was cleaned, kept in oxygen and restored to its nest ledge two days later, with the appropriate nickname of "Phoenix."

Interesting facts abound. Each day, each young Peregrine consumes the equivalent of its own body weight in prey. The main food items are rock doves and mourning doves, but blue jays and robins are sometimes added to the larder. When a rock dove is driven into the water, only the female peregrine has sufficient strength to lift it out and carry it to the nest.

One 1991 nesting on the Marine Parkway bridge was of interest on five counts. The mating was between a brother and sister, raised on the New York Hospital ledge in 1989. When the adult female was killed, the male was hard pressed yet able to bring sufficient food for the young. When a nestling fell to a beam 25 feet below the nest ledge, Saul not only climbed a 100-foot ladder to restore it, but arranged with the bridge authorities to stop all bridge traffic for a few minutes, for fear the returned bird or its nestmate might be frightened and flutter down onto the heavily trafficked roadway. Young in this nest had an occasional ride of nearly 90 feet whenever the counterweight, on which the nest box was installed, was lowered.

An Appendix documents success and failure at each nest year. Nests on building ledges, a behaviour that began only in 1988, had twice the success, raising an average of 2.67 young that survived to dispersal, versus 1.25 chicks per pair nesting on bridges.

No longer is the peregrine a bird only of remote sites (none of the cliff sites on the Hudson River have yet been reoccupied), but instead they now net in large cities. To Saul Frank, the sight of a peregrine flying, soaring or diving at prey, is "a spectacle for the eyes and a balm for the soul."

C. STUART HOUSTON

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ENVIRONMENT

The Atlas of Endangered Animals and **The Atlas of Endangered Places**

By S. Pollock. 1993. Facts on File, New York. each 64 pp., illus. $16.95 each.

These two volumes are part of a new series aimed at raising environmental awareness of young adults. They are inviting books, with large fonts and plenty of large colour pictures which should attract the teenage eye.

Both books follow the same format in dividing up the world into 18 major regions, which are then dealt with separately. Each region is depicted in a full-page map with symbols showing environmental hotspots that relate to the text and a world map as an inset. In *The Atlas of Endangered Animals*, a number of animals, variously classified as vulnerable, rare, endangered, or extinct, are pictured opposite the area map, along with a brief synopsis of each species' distribution, lifestyle and causes of decline. *The Atlas of Endangered Places* presents brief case histories of ecologically sensitive areas that have been altered recently by natural and unnatural causes, and delves more deeply into the problems faced by particular regions, such as desertification in Northern Africa and the loss of rain forests in South America.

Although the books generally do a thorough job, there are a few inaccuracies (e.g., crown-of-thorn starfish do not spawn their eggs on algal mats, and the Alaska pipeline does not go through Canada) and some omissions (e.g., little mention of radioactivity problems in the former Soviet Union or of acid rain north of the American border). Overpopulation in particular is a problem of global scale that is not given the importance it deserves. The choice of endangered animals presented also reflects the public bias for warm cuddly animals (55 mammals and marsupials and 30 birds vs 3 fish and 4 invertebrate species), rather than the reality.

The books are full of facts and statistics which will be useful for essays and which were up-to-date at the time of printing. It is inevitable they will soon be outdated. Already, the maps of Europe and Africa need to be revised with the appearance of the Czech Republic, Slovakia, and Eritrea. Suriname's "largely untouched forests" may soon disappear as recent plans to log up to a third of the country's forested areas go ahead. At least one of the four wintering populations of Siberian cranes mentioned was not sighted last winter and may no longer exist.

The statistics are often difficult to visualise, and not just by young minds. For example, exactly how much is 73 million cubic meters of domestic and industrial waste, the quantity which is dumped into the Danube by the city of Bratislavia? Expressed in terms of bathtubs, it would be something like 130 million, or nearly 20 000 Olympic-size swimming pools. These are still large numbers, but they are easier to understand.

The tone of the books is very objective throughout: no side is taken and the facts are simply presented without assigning blame to particular people. Although a few success stories are told about habitats and species that were pulled back from the brink on time, the overall feeling one gets, from these and most other books on environmental problems, is one of doom and gloom. Young people may therefore perceive environmentalism as an impossible struggle. Raising environmental awareness of the young is seen as a large part of the solution to solving our environmental problems; yet, there is a risk of creating an environmental fatigue syndrome in the very people that hold the keys to a better future. With this caveat in mind, I would still recommend these books for the breadth of topics they cover, which makes them good references on a young person's bookshelf.

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Practical Handbook for Wetland Identification and Delineation

By John Grimson Lyon. 1994. Lewis Publishers, Boca Raton, Florida. 208 pp, illus. U.S. $59 in U.S.A.; U.S. $72 elsewhere.

This book of wetland identification will be of little interest for use in Canada, as it is strongly focused on the United States and its regulations relating to permitting and developing wetlands. People interested in wetlands in the United States would also find the book of limited use, because there are continued references to seeking additional information in other books or references while the book itself contains little substantive information.

This handbook is obviously not written by a biologist as there are all sorts of minor yet irritating errors. The author suggests that familial and generic names are the same when describing briefly the binomial system of classification (page 67). His description of wetlands ignores fens as forested wetlands and neglects bogs entirely which makes one wonder how comprehensive this book is. There are serious omissions in that there is no discussion of rare or endangered species in wetlands nor discussion of the relevance of significant breeding locations of wetlands for herons, raptors, or amphibians.

There are also un unacceptable number of grammatical errors. In places the reader has to try and sort out what the relevant point is. In other places the text is unnecessarily pompous and convoluted and it is certainly not an easy read. Considering the large number of good books available on wetlands and the excellent provincial and national guides to wetlands, I would not consider this a useful addition to a naturalist's library.

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NEW TITLES

Zoology

*__Anolis lizards of the Caribbean: ecology, evolution, and plate tectonics.__ 1995. By J. Roughgarden. Oxford University Press, Don Mills, Ontario. xi+200 pp., illus. $44.50.

†**Artificial nest structures for ospreys: a construction manual.** 1994. By P. J. Ewins. Canadian Wildlife Service, Toronto. 39 pp., illus.

*__Bats: a community perspective.__ 1995. By J. S. Finley. Cambridge University Press, New York. xi+167 pp., illus. U.S.$19.95.

Biology takes form: animal morphology and the German universities, 1800 - 1900. 1995. By. L. K. Nyhart. University of Chicago Press, Chicago. c392 pp., illus. Cloth U.S.$75; paper U.S.$24.95.

*__Bird life of woodland and forest.__ 1995. By R. Fuller. Cambridge University Press, New York. xiii+244 pp., illus. U.S.$64.95.

†**The birds of Great Slave Lake, Northwest Territories, Canada.** 1994. By J. Sirois. Ecology North, Yellowknife. 36 pp. $3.

†**The birds of the Northwest Territories.** 1994. By J. Sirois and D. McRae. Canadian Wildlife Service, Yellowknife. 28 pp., illus.

*__Bird song: biological themes and variations.__ 1995. By C. K. Catchpole and P. J. B. Slater. viii+248 pp., illus. U.S.$32.95.

†**The black-tailed prairie dog.** 1995. By J. L. Hoogland. Chicago University Press, Chicago. c576 pp., illus. Cloth U.S.$90; paper U.S.$34.95.

Bugs in the system: insects and their impact on human affairs. 1995. By M. R. Berenbaum. Addison-Wesley, New York. xiii+377 pp., illus. U.S.$25.

†**A century of avifauna changes in western North America**. 1994. Edited by J. R. Jehl and N. K. Johnson. Cooper Ornithological Society, Camarill, California. v+348 pp., illus. U.S.$40.

Ethics on the ark: zoos, animal welfare, and wildlife conservation. 1995. Edited by B. G. Norton, M. Hutchins, E. F. Stevens, and T. Maple. Smithsonian Institute Press, Washington. 432 pp., illus. U.S.$32.50.

*__A field guide to shells: Atlantic and Gulf coasts and the West Indies.__ 1995. By R. T. Abbott and P. A. Morris. Peterson Field Guide Series. Houghton Mifflin, Boston. 350 pp., illus.

*__Flammulated, boreal, and great gray owls in the United States: a technical conservation assessment.__ 1994. Edited by G. D. Hayward and J. Verner. General Technical Report RM-253. Rocky Mountain Forest & Range Experimental Station, Fort Collins, Colorado. ix+213 pp.+ maps.

*__Lake, river, and sea-run fishes of Canada.__ 1994. By F. H. Wooding. Harbour Publishing, Madira Park, British Columbia. 278 pp., illus. $32.95.

Lemurs of Madagascar. 1995. By R. A. Mittermeier, I. Tattersall, W. R. Konstant, D. M. Meyers, and R. B. Mast. Conservation International distributed by University of Chicago Press, Chicago. c356 pp., illus. U.S.$40.

†**Lone star dinosaurs.** 1995. By L. Jacobs. Texas A&M University Press, College Station. 170 pp., illus. U.S.$27.95.

†**The minds of birds**. 1995. By A. F. Skutch. Texas A&M University Press, College Station. 200 pp., illus. U.S.$29.95.

*__The northern goshawk: ecology and management.__ 1995. Edited by W. M. Block, M. L. Morrison, and M. H. Reiser. Studies in Avian Biology No. 16. Cooper Ornithological Society, c/o W. Wehtje, Western Foundation of Vertebrate Zoology, 439 Calle San Pablo, California 93010. vi+136 pp., illus. U.S.$16.

†**The patient predator: foraging and population ecology of the great blue heron *Ardea herodias* in British Columbia.** Canadian Wildlife Service, Delta, British Columbia. 44 pp., illus. Free.

†**Polygyny and sexual selection in red-winged blackbirds.** 1995. By W. A. Searcy and K. Yasukawa. Princeton University Press, Princeton. xviii+312 pp., illus. Cloth U.S.$55; paper U.S.$29.95.

†**Radiation hazards to fish, wildlife, and invertebrates: a synoptic review.** 1994. By R. Eisler. Biological Report 26. National Biological Service, Washington. iv+124 pp., illus.

†**The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States.** 1994. Edited by L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski. U.S.D.A. Forestry Service General Technical Report RM-254. Rocky Mountain Forest and Range Experimental Station, Fort Collins, Colorado. vii+184 pp.+map. Free.

†**Sibley fishes**. 1994. By S. A. Stephenson and W. T. Momot. Occasional Paper No. 15. Lakehead University Centre for Northern Studies, Thunder Bay. iv+133 pp., illus. $6.

*__Terns of Europe and North America.__ 1995. By K. M. Olsen and H. Larsson. Princeton University Press, Princeton. 207 pp., illus. U.S.$39.50.

†**Underwater guide: Mediterranean Sea fishes.** 1995. By R. A. Patzner and H. Moosleitner. English and German. Naglschmid-Verlag, Stuttgart. 168 pp., illus.

Vertebrate paleontology in the neotropics: the miocene fauna of La Venta, Colombia. 1995. Edited by R. F. Kay, R. H. Madden, R. L. Cifelli, and J. J. Fynn. Smithsonian Institute Press, Washington. 406 pp., illus. U.S.$80.

*__Where to watch birds in South America.__ 1995. By N. Wheatly. Princeton University Press, Princeton. 431 pp., illus. U.S.$35.

†**Wildlife and recreationists: co-existence through management and research.** 1995. Edited by R. L. Knight and R.J. Gutzwiller. Island Press, Washington. xvii+372 pp., illus. Cloth U.S.$49.95; Paper U.S.$27.50.

*__A world checklist of birds.__ 1994. By B. L. Monroe, Jr. and C. G. Sibley. Yale University Press, New Haven, Connecticut. xix+393 pp. U.S.$45.

Botany

Alpines: the illustrated dictionary. 1995. By C. Innes. Timber Press, Portland, Oregon. 195 pp., illus. U.S.$39.95.

Botanical Latin. 1995. By W. T. Stearn. 4th edition. Timber Press, Portland, Oregon. 560 pp., illus. U.S.$39.95.

Ericaceae part II: the superior-ovaried genera (Monotropoideae, Pyroloideae, Rhododendroideae, and Vaccinioideae). 1995. Edited by J. L. Luteyn. New York Botanical Garden, Bronx. U.S.$85.

A field guide to palms of the Americas. 1995. By A. Henderson, G. Galeano, and R. Bernal. Princeton University Press, Princeton. 352 pp., illus. U.S.$75.

A field guide to woody plants of northwest South America: Colombia, Ecuador, Peru. 1994. By A. H. Gentry. Conservation International distributed by University of Chicago Press, Chicago. 918 pp., illus. U.S.$45.

Ironwood: an ecological and cultural keystone of the Sonora Desert. 1994. Edited by G. P. Nabhan and J. L. Carr. Conservation International distributed by Chicago University Press, Chicago. 92 pp., illus. U.S.$10.95.

†**The private life of plants.** 1995. By D. Attenborough. Princeton University Press, Princeton. 320 pp., illus. U.S.$26.95.

†**Rare vascular plants in the Northwest Territories.** 1995. By C. L. McJannet, G. W. Argus, and W. J. Cody. Syllogeus No. 73. Canadian Museum of Nature, Ottawa. 104 pp., illus. Free.

Environment

†**Atlas of endangered resources.** 1995. By S. Pollock. Facts on File, New York. 64 pp., illus. U.S.$16.95.

†**Conservation biology in Australia and Oceania.** 1994. Edited by C. Moritz and J. Kikkawa. Surrey Beatty, Chipping Norton, Australia. A$93; U.S.$75.

*__Darwinism evolving: system dynamics and the genealogy of natural selection.__ 1995. By D. J. Depew and R. H. Weber. MIT Press, Cambridge, Massachusetts. xiii+588 pp. U.S.$49.95.

†**Endangered ecosystems of the United States: a preliminary assessment of loss and degradation.** 1995. By R. F. Noss, E. T. LaRoe, III, and J. M. Scott. Biological Report 28. National Biological Service, Washington. 58 pp., illus. Free.

*__From a biological point-of-view.__ 1994. By E. Sober. Cambridge University Press, New York. x+255 pp., illus.

†**Leks.** 1995. By J. Höglund and R. V. Alatalo. Princeton University Press, Princeton. 248pp., illus. Cloth U.S.$49.50; paper U.S.$24.95.

†**Macroecology.** 1995. By J. H. Brown. University of Chicago Press, Chicago. xiii+269 pp., illus. Cloth U.S.$42.50; paper U.S.$15.95.

†**Memorabilia of research on the Dundas Marsh, Hamilton, Ontario, Canada 1946 to 1948**. 1995. By W. W. Judd. Phelps, London. 81 pp., illus. $10.

†**The new ecological order.** 1995. By L. Ferry. University of Chicago Press, Chicago. 176 pp., illus. Cloth U.S.$34.95; paper U.S.$14.95.

†**Peterson first guide to forests.** 1994. By J. Krichen. Houghton Mifflin, Boston. 128 pp., illus. U.S.$4.95.

†**Primer of ecology.** 1995. By N. J. Gotelli. Sinauer, Sunderland, New Jersey. xiv+206 pp., illus. U.S.$18.95.

†**The reconstruction of fragmented ecosystems**. 1995. Edited by D. A. Saunders, B. J. Hobbs, and P. R. Ehrlich. Surrey Beatty, Chipping Norton, Australia. xv+326 pp., illus.

*__Reinventing nature? responses to postmodern deconstruction.__ 1995. Island Press, Washington. xvii+186 pp., illus. Cloth U.S.$34.95; paper U.S.$17.95.

*__Restoration of endangered species: conceptual issues, planning, and implementation.__ 1995. Edited by M. L. Bowles and C. J. Whelan. Cambridge University Press, New York. xiii+394 pp., illus. U.S.$49.95.

*__Saving nature's legacy: protecting and restoring biodiversity.__ 1994. By R. F. Noss and A. Y. Cooperhider. Island Press, Washington. xxvii+416 pp., illus. Cloth U.S.$48; paper U.S.$27.50.

Serengeti II: dynamics, management, and conservation of an ecosystem. 1995. Edited by A. R. E. Sinclair and P. Arcese. University of Chicago Press, Chicago. c704 pp., illus. Cloth U.S.$90; paper U.S.$34.

The Tambopata - Candamo - Rio Heath region of southeastern Peru: a biological assessment. 1995. By R. B. Foster, et al. Conservation International distributed by University of Chicago Press, Chicago. c192 pp., illus. U.S.$19.95.

Miscellaneous

*__American women afield: writings by pioneering women naturalists.__ 1995. By M. M. Bonta. Texas A&M University Press, College Station. xvi+248 pp., illus. Cloth U.S.$35; paper U.S.$15.95.

The different naturalist: Robert Boyle and the philosophy of experiment. 1995. By R. M. Sargent. University of Chicago Press, Chicago. c368 pp. Cloth U.S.$65; paper U.S.$26.

†**The ice-age history of Alaska national parks.** 1995. By S.A. Elias. Smithsonian Institute Press, Washington. 224 pp., illus. U.S.$16.95.

Secrets of the night sky: the most amazing things in the universe you can see with the naked eye. 1995. By B. Berman. Morrow, New York. xiii+320 pp., illus. U.S.$23.

Books for Young Naturalists

Back off: animal defenses; Look again: animal disguises. 1995. By P. Mirocha and R. Lauffer. Scientific American Books for Young Readers, New York. Each 12 pp., illus. U.S.$10.95.

Butterfly story. 1995. By A. Hariton. Dutton, New York. 30 pp., illus. U.S.$14.99.

Counting on people: elementary population and environmental activities. 1994. By P. Wasserman and A. Scullard. Zero Population Growth, Washington. 147 pp., illus. U.S.$19.99.

Insect-eating plants. 1995. By L. P. Kite. Millbrook Press, Brookfield, Connecticut. 61 pp., illus. U.S.$15.90.

Lynx. 1995. By J. Schneider. Carolrhoda, Minneapolis. 47 pp., illus. U.S.$14.96.

Our planet Earth. 1995. By S. Parker. Facts on File, New York. 48 pp., illus. U.S.$9.95.

Outside and inside birds. 1994. By S. Marle. Bradbury Press, New York. 40 pp., illus. U.S.$15.95.

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†available for review

Advice to Contributors

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

Manuscripts

Please submit, **to the Editor**, in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

Type the manuscript on standard-size paper, if possible use paper with numbered lines, **double-space throughout**, leave generous margins to allow for copy marking, and **number each page**. For Articles and Notes provide a bibliographic strip, an abstract and a list of key words. Generally words should not be abbreviated but use SI symbols for units of measure. Underline only words meant to appear in italics. The names of authors of scientific names should be omitted except in taxonomic manuscripts or other papers involving nomenclatural problems. "Standard" common names (with initial letters capitalized) should be used at least once for all species of higher animals and plants; all should also be identified by scientific name.

The names of journals in the Literature Cited should be written out in full. Unpublished reports should not be cited here but placed in the text or in a separate documents section. Next list the captions for figures (numbered in arabic numerals and typed together on a separate page) and present the tables (each titled, numbered consecutively in arabic numerals, and placed on a separate page). Mark in the margin of the text the places for the figures and tables.

Extensive tabular or other supplementary material not essential to the text, typed neatly and headed by the title of the paper and the author's name and address, should be submitted in duplicate on letter-size paper for the Editor to place in the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Canada K1A 0S2. A notation in the published text should state that the material is available, at a nominal charge, from the Depository.

The **Council of Biology Editors Style Manual**, Fourth edition (1978) available from the American Institute of Biological Sciences, and **The Canadian Style: A Guide to Writing and Editing**, Department of the Secretary of State and Dundurn Press Ltd (1985) are recommended as general guides to contributors but check recent issues (particularly in literature cited) for exceptions in journal format. Either "British" or "American" spellings are acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary** and le **Grand Larousse Encyclopédique** are the authorities for spelling.

Illustrations

Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

Reviewing Policy

Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

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Francis R. Cook, Editor
RR 3 North Augusta, Ontario K0G 1R0

TABLE OF CONTENTS *(concluded)*

Mailing date of the previous issue 109(1) : 21 July 1995

Articles

Notes

concluded on inside back co

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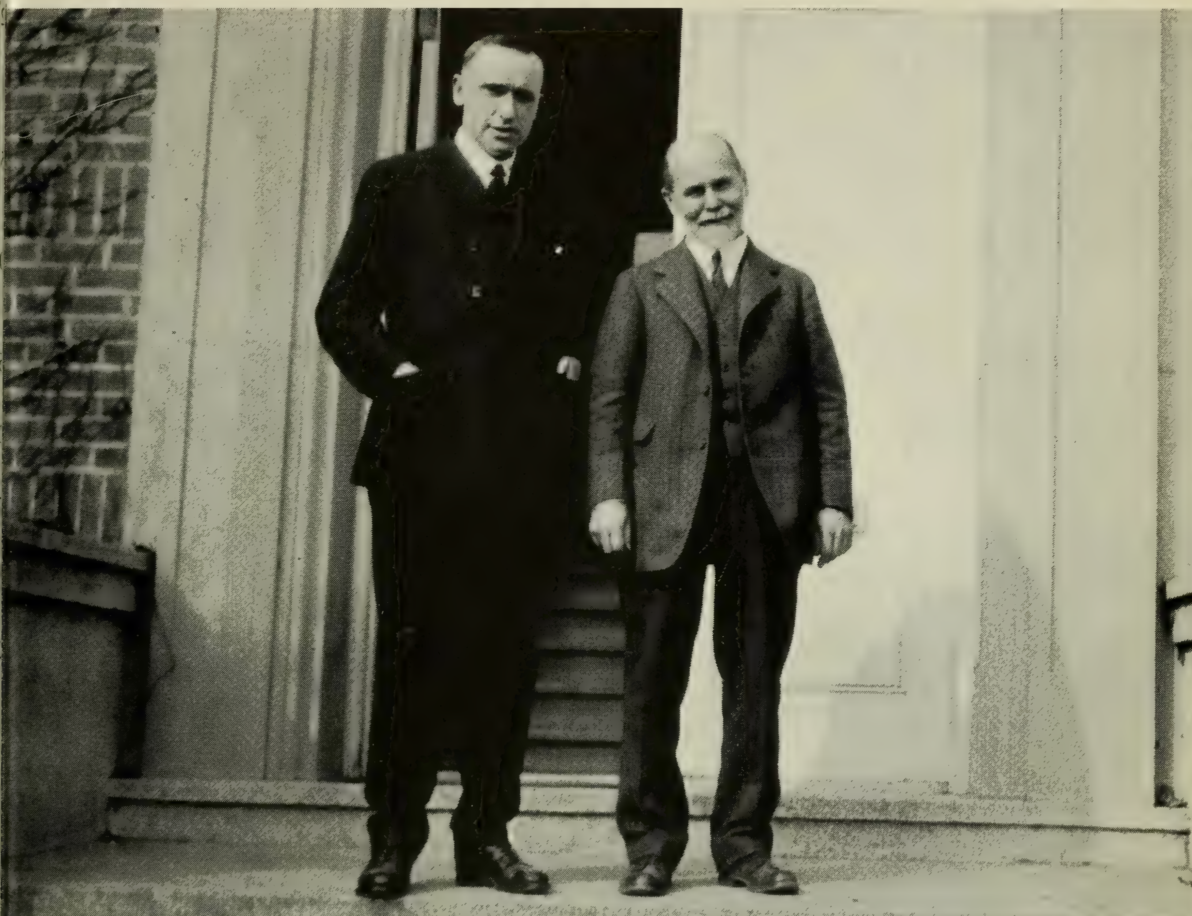


Special Issue: The History of the Exploration of the Vascular Flora of Canada, Saint-Pierre et Miquelon, and Greenland

Published in Cooperation with THE MISSOURI BOTANICAL GARDEN

Volume 109, Number 3 **July-September 1995**

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency The Right Honourable Roméo LeBlanc, P.C., C.C., C.M.M., C.D.,
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Those wishing to communicate with the Club should address correspondence to: The Ottawa Field-Naturalists' Club, Box P.O. Box 35069, Westgate P.O. Ottawa, Canada K1Z 1A2. For information on Club activities telephone (613) 722-3050.

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

All manuscripts intended for publication should be addressed to the Editor with the exception of book reviews which should go directly to Book Review Editor.

Subscriptions and Membership
Subscription rates for individuals are $23 per calendar year. Libraries and other institutions may subscribe at the rate of $38 per year (volume). The Ottawa Field-Naturalists' Club annual membership fee of $23 includes a subscription to *The Canadian Field-Naturalist*. All foreign subscribers (including USA) must add an additional $5.00 to cover postage. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O. Ottawa, Canada K1Z 1A2.
Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue: July-September 1995 (December 1995).

Back Numbers and Index
Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club*, 1879-1886, and *The Ottawa Naturalist*, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Frère Marie-Victorin (viewer's left) and M. L. Fernald at the front entrance to the Gray Herbarium of Harvard University, probably during the period 1924–1928 (courtesy of l'Université de Montréal).

The Canadian Field-Naturalist

Volume 109, Number 3 July–September 1995

The History of the Exploration of the Vascular Flora of Canada

James S. Pringle

Royal Botanical Gardens, Box 399, Hamilton, Ontario, Canada L8N 3H8

Pringle, James S. 1995. The history of the exploration of the vascular flora of Canada. Canadian Field-Naturalist 109(3): 291–356.

Floristic studies in Canada began with the exploring expeditions of the late eighteenth and early nineteenth centuries, e.g., Alejandro Malaspina's and W. E. Parry's. In Labrador, early specimens were collected by Moravian missionaries. Notable events in the 1820s and 1830s included David Douglas's horticultural expedition in the portion of the Oregon Territory that is now British Columbia, and Thomas Drummond's exploration of the prairies and the Rockies; and W. J. Hooker's requests for specimens for his *Flora Boreali-Americana* encouraged botanizing in eastern British North America. Floristic study was stimulated by the inclusion of botany in university curricula ca. 1860, and by local scientific societies that encouraged avocational plant collecting ca. 1860-1905. In Québec, from the 1860s to the 1960s, much floristic study was conducted by monks and priests. Government-sponsored exploration greatly increased following Confederation in 1867 and the annexation of Rupert's Land in 1869, culminating in John Macoun's expeditions to western Canada in the 1870s and 1880s. Federally supported studies, largely concentrated on boreal regions, dominated in the early and mid-twentieth century. Local studies have burgeoned in recent years, often in relation to the preservation of natural areas.

Key Words: Canada history, flora.

In every part of the world, people are aware of the plant life on which they depend, and folk classification of plants is as ancient as human occupation. Although the early peoples of Canada doubtless included individuals recognized as experts on plants by their contemporaries, botanical archaeology and ethnobotany are not within the scope of the present paper. The subject matter of this paper, and that of its companion papers on the botanical exploration of Greenland and of Saint-Pierre et Miquelon, is restricted to the recorded history of floristics. It is further restricted to those components of botanical exploration and authorship that contributed to the scientific knowledge of the flora, i.e. the collecting of specimens that were deposited in institutional herbaria and that documented published reports, and writing that incorporated scientific nomenclature (or directly preceded such publications). Also, especially in its coverage of events of the twentieth century, it is largely restricted to the history of vascular-plant floristics.

Early History: European exploration and settlement along the east coast and St. Lawrence River

The recorded history of the botanical exploration of Canada, like that of the eastern seaboard of the United States, began with observations of the vegetation along the coasts of the present Atlantic Provinces and in the St. Lawrence Valley. These observations were recorded during the sixteenth and seventeenth centuries by English and French explorers and by French missionaries and settlers. (For notes on and citations of some of this early literature see, *inter alia*, Penhallow 1888; Adams et al. 1928-1951: 17: 294-295; Voss 1978: 1-2; and Chartrand et al. 1987: 45-46.)

The earliest herbarium specimens that can reasonably be assumed to be from present-day Canada, considering phytogeographic and historical factors, are those of "the French apothecary" from the herbarium of Joachim Burser (Juel 1931). These were described in 1620 by Caspar Bauhin in his *Prodromus Theatri Botanici*, and Bauhin's works were cited by Linnaeus in his *Species Plantarum*. Some of the species are scarcely amenable to transplanting, so it is probable that the specimens were prepared from wild plants rather than from plants cultivated in a French garden (as has been suggest-

ed). Boivin (1980, 1988) has speculated that these specimens were collected by Louis Hébert (1575-1627), an apothecary who lived at Port-Royal (now Annapolis Royal, Nova Scotia) from 1610 to 1613, returned to France for four years, then spent the rest of his life at Québec (Bennett 1966).

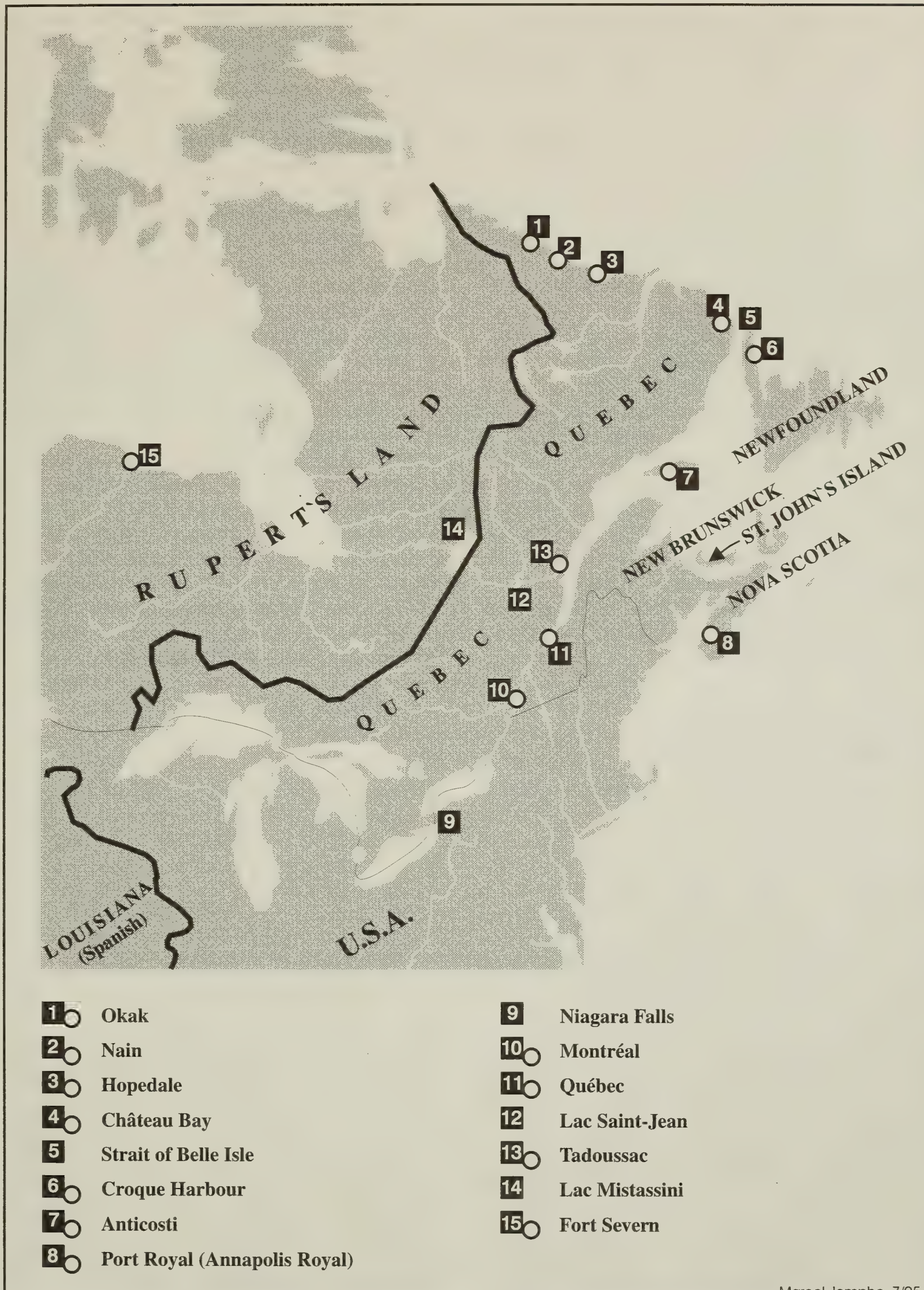
The demand for North American plants by horticulturists in Britain and continental Europe was late in contributing significantly to the knowledge of the Canadian flora, even though the earliest explorations of North America by both the British and the French were concentrated on the shores of the Gulf of St. Lawrence, and the French missions and settlements in Canada were as early as the British colonies in Virginia. Some of the early French ventures ended disastrously, and the survivors were in no condition to preserve horticultural material until spring permitted their departure. Nevertheless, by the middle of the seventeenth century, at least a few species had reached European gardens from New France. In 1536 it is believed that Jacques Cartier brought back *Thuja occidentalis* L.—the "annedda" that had saved his party from scurvy, *Pinus strobus* L., and *Acer saccharum* Marshall. In the 1620s Récollet missionaries contributed species including *Lilium canadense* L. and *Lobelia cardinalis* L. from the present site of Québec City, and *Monarda fistulosa* L. from the Penetanguishene Peninsula near the south end of Lake Huron's Georgian Bay. When settlements were established at Port-Royal, Québec [City], and Tadoussac (Map 1) a few years later, more species were introduced to European horticulture. Samuel de Champlain, Marc Lescarbot, and Louis Hébert are among the historic figures credited with some of these introductions (Rousseau 1937, 1957; Chartrand et al. 1987; Pringle 1988; and references cited therein).

Little further botanical activity occurred in New France until nearly the end of the seventeenth century, at which time the Académie Royale des Sciences in Paris began organized efforts to acquire natural-history specimens from distant lands. Michel Sarrazin (1659-1734), royal physician at Québec from 1697 to 1734, for whom the pitcher-plant genus *Sarracenia* was later named by Linnaeus, had sent specimens to Tournefort in 1698, and was appointed a "correspondent" charged with obtaining such specimens. For many years Sarrazin sent quantities of herbarium specimens from Québec and Newfoundland to Tournefort and later to Sébastien Vaillant (who distributed specimens to William Sherard in England) and Antoine de Jussieu. He also sent "a very large number of plants and seeds" for the botanical garden at Paris. Notes accompanying the specimens were, with credit duly given, incorporated into a manuscript on Canadian plants by Vaillant (Laflamme 1888; Rousseau 1957, 1969b; Clokie 1964; Boivin 1977, 1980; Chartrand et al. 1987). Another French surgeon, named Dièreville, visited Acadia in 1699 and collected 25 specimens for Tournefort, including the species now known as *Diervilla lonicera* L. (Rousseau 1969a; Boivin 1988).

For two years beginning in the autumn of 1747, the acting governor of New France was Roland-Michel Barrin de La Galissonière, Marquis de La Galissonière (1693-1756, on whom see Taillemite 1974), who was keenly interested in the natural sciences and corresponded with leading European scholars in several fields, including the botanist Bernard de Jussieu. Barrin de La Galissonière arranged for the assistance of the commandants of the forts in New France in obtaining botanical and other natural-history specimens for French botanists. Sarrazin's successor as royal physician at Québec, Jean-François Gaultier (1708-1756; commemorated in the genus name *Gaultheria* L.), was appointed "correspondent" of H.-L. Duhamel du Monceau by the Académie, and likewise sent plants and botanical specimens to Paris. Presumably at the instigation of Duhamel and the Jussieus, Gaultier planned a six-volume illustrated work on the plants of northern North America, but because of Gaultier's death in 1756 and the Seven Years' War, this never materialized (Rousseau 1957; Boivin 1974, 1980; Chartrand et al. 1987). Other naturalists in New France during this period, who also made floristic and horticultural contributions, have been mentioned by Chartrand et al. (1987).

Meanwhile, a British presence had been established in Newfoundland to serve the fishing fleet, and the British and French were competing for the fur trade on the shores of Hudson Bay. The oldest botanical specimens from Newfoundland appear to be those collected in 1699 by William Hay, a ship's surgeon, for James Petiver. Petiver was also the recipient of some of the earliest known specimens from Hudson Bay, collected in 1708 by John Smart, another ship's surgeon, who also contributed specimens from Maryland. About the same time, Sir Hans Sloane received specimens obtained from the shores of Hudson Bay by a Mr. Lide. All of these specimens eventually became part of the Sloane Herbarium (Dandy 1958; Reveal 1983). Also about this time, William Sherard acquired specimens (now at Oxford) from Hudson Bay collected by Richard Tilden (or said to have been collected by Tilden, although one might suspect that he was an intermediary who received and distributed specimens that he, like his friends Petiver and Sloane, had requested someone else to collect) (Clokie 1964). Other early plant collecting on the shores of Hudson Bay and James Bay, which presumably concentrated on living plants for horticultural purposes rather than on herbarium specimens, has been noted by Houston (1993).

An event of major significance both to botanical nomenclature and to the knowledge of the Canadian



Map 1. Significant sites of early botanical exploration in present-day eastern Canada. Boundaries are shown as of 1784, following the Treaty of Paris.

flora was Pehr Kalm's expedition to North America in 1749 (on which see Juel and Harshberger 1930; Rousseau et al. 1977; Chartrand et al. 1987). Kalm (1716-1779), a student and friend of Linnaeus, was sent by the Royal Swedish Academy of Science to discover economic plants that might succeed in Sweden, and was instructed to devote as much attention as possible to Canada (Jarrell 1979). From present-day New York State Kalm traveled to Montréal; thence to Québec, where he joined Gaultier in botanizing along the St. Lawrence as far as Les Éboulements; and then to Niagara Falls, where he discovered the St. John's-wort, *Hypericum kalmianum* L., named for him by Linnaeus. (The genus *Kalmia* L., although not so named until later, was already known to European botanists.) Kalm's memoirs constitute a valuable record of early Canadian society, and many of his herbarium specimens typify names published in *Species Plantarum*.

John Bartram, a Philadelphia botanist who sent specimens to Linnaeus, indicated that his botanical explorations in 1743 extended to "Canada," but this reflects the inconsistent use of the name prior to the American Revolution. Bartram's "Canada" was the south side of Lake Ontario (which had been under French control until 1763), specifically the vicinity of present-day Oneida, New York.

After the Seven Years' War and its North American manifestation, traditionally (at least in the United States) known as the French and Indian War, in 1756-1763, settlement of Canada proceeded slowly for some time. In Newfoundland particularly, although fishing off the coast was vital to the British economy, permanent settlements were viewed as potential liabilities. Not until the arrival of the Loyalists after the American Revolution was there extensive settlement by English-speaking colonists, mostly in Nova Scotia and in Upper Canada (now southern Ontario). [Prior to 1841, the name Canada applied only to that part of present-day Québec, Labrador, and Ontario within the Great Lakes-St. Lawrence watershed, the Québec-Labrador portion being Lower Canada, and the Ontario portion being Upper Canada. Lower and Upper Canada became the United Province of Canada in 1841, but for such purposes as shipping addresses they retained their respective identities as Canada East and Canada West. Upon Confederation in 1867, Canada included Nova Scotia and New Brunswick as well. The present national boundaries evolved as other provinces and territories were added, beginning with the Hudson's Bay Company lands and British Columbia in 1870 and 1871, and culminating with Newfoundland and Labrador in 1949.]

The Early British Colonial Period: Exploration of Labrador, the interior, and the west coast

Ironically, the first part of present-day Canada to receive significant floristic attention after the Treaty of Paris (and coincidentally after the publication of Linnaeus's *Species Plantarum*) was the cold and rocky coast of Labrador. Joseph Banks (1743-1820) lived near the British headquarters of the Moravian Church in London, and as soon as the Moravians began to reconnoiter Labrador for mission sites, Banks asked them to provide him with botanical specimens. Banks received his first Labrador specimens from Jens Haven (1724-1797), the expedition leader, and his companions in 1765. The next year Banks himself sailed for Newfoundland and Labrador and botanized on both sides of the Strait of Belle Isle, especially at Croque Harbour, Newfoundland, and Château Bay, Labrador (Map 1) (Lysaght 1971; O'Brian 1987; Shchepanek and Darbyshire 1990, q.v. for map of collecting localities). Species new to science collected by Banks on this expedition, with currently accepted names typified by his specimens, include *Streptopus lanceolatus* (Aiton) Reveal, *Clintonia borealis* (Aiton) Raf., *Listera convallarioides* (Sw.) Nutt. ex Torr., and *Petasites palmatus* (Aiton) A. Gray.

Moravian missionaries contributed botanical specimens from coastal Labrador from the 1760s until the 1940s. By far the most notable of the early missionaries in this context was Benjamin Gottlieb Kohlmeister (1756-1844), a native of Poland, who served at Okak, Hopedale, and Nain from 1790 to 1824. Kohlmeister's specimens reached many of the leading botanists of his time, including Schweinitz, Pursh, Rafinesque, and later Torrey and Gray in the United States; Banks and W. J. Hooker in Britain; and Schreber and Schrank in Bavaria. Schrank (1818) published a paper on the flora of Labrador based on Kohlmeister's specimens. Pursh (1813) based a number of new species described in his *Flora Americae Septentrionalis* on Kohlmeister's specimens, including the orchid now called *Platanthera dilatata* (Pursh) Lindl. ex L. C. Beck, and several of the other botanists named above described new species from these collections.

Prominent among the other Moravian missionaries who sent botanical specimens from Labrador were Johannes Lundberg (1786-1856), Christian Benedict Henn (1780-1844), Johann Georg Herzberg (1791-1864), Carl Gottfried Albrecht (1800-1888), Ferdinand Kruth (1804-1863), Samuel Weiz (1823-1888), (Gottlieb) Adolph Stecker (1859-1939), and (Richard) Paul Hettasch (1873-1949). (For biographical notes on these and other Moravian missionary naturalists, see Pringle 1992 and Cayouette and Darbyshire 1994; the princi-

pal sites of plant collecting by Moravians in Labrador are shown in Map 1.) During the mid-nineteenth century, Moravian officials in Europe realized that the sale of herbarium specimens could contribute to the support of the missions and encouraged collecting in quantity. The original purchasers often further divided their acquisitions for exchange purposes. Such was the history of many Labrador specimens acquired by Asa Gray for his herbarium and cited in his publications (and later by M. L. Fernald and other Harvard botanists).

Other early northern specimens were collected by Andrew Graham (1733-1815), Hudson's Bay Company master at Fort Severn on Hudson Bay (Map 1), and were acquired by Banks in 1783, evidently from H.B.C. surgeon Thomas Hutchins (ca. 1742-1790), who may also have participated in the collecting (Williams 1983, and references cited therein; Houston 1989, 1994; Houston and Houston 1991a,b). Some new species described by Pursh (1813), e.g., the orchid now called *Platanthera obtusata* (Banks ex Pursh) Lindl., were based on specimens that Banks had acquired from Hutchins.

The statement occasionally encountered that the horticultural explorer John Fraser, Sr. (1750-1811), spent some four years in Newfoundland is incorrect, the result of connecting the date of a visit in 1780 with that of a brief stop en route to the southern United States in 1784. Evidently he brought some horticultural material back to England for William Forsyth, Sr., Curator of the Chelsea Physic Garden, in 1780, but no definite records or specimens are known.

Spanish claims included the coast of present-day British Columbia until 1789, at which time a treaty with Britain provided that either party might fish, trade, or settle unoccupied sites north of California. In 1791, the historic Spanish naval expedition led by Alejandro Malaspina explored the Pacific shores from México to Alaska. Nootka Sound, the site of a Spanish settlement (transferred to Britain in 1792) on the Pacific side of Vancouver Island, served as this expedition's base of operations for exploration of the British Columbia coast. Botanical specimens, including the type of the name of the Nootka Rose, *Rosa nutkana* C. Presl, were collected by the expedition naturalist, Thaddeus Peregrinus Xavierus Haenke (1761-1816), a noted Bohemian botanist. These were subsequently published upon by K. B. Presl and collaborators (McKelvey 1956; Stearn 1973; and other publications on Haenke cited by Stafleu and Cowan 1979). The following year a Spanish naval expedition commanded by Juan Francisco de la Bodega y Quadra sailed from San Blas, México, to Nootka. This party, which remained at Nootka for nearly five months, included the botanist José Mariano Mociño (1757-1820), who wrote a paper on his observations around Nootka (see Langman 1964, for bibliographic details). Numerous specimens collected by Mociño at this time are now in the Sessé & Mociño herbarium at Madrid. Mociño was accompanied on this expedition by Atanasio Echeverría y Godoy, an artist; copies of his botanical illustrations typified several names published in de Candolle's *Prodromus*, e.g. *Claytonia parviflora* Moç. ex DC., for the species now called *Montia parviflora* (Moç. ex DC.) Greene (McKelvey 1956; McVaugh 1977; and other publications on Mociño cited by Stafleu and Cowan 1981).

A greater direct contribution to the knowledge of the British Columbia flora, especially as reflected in Hooker's *Flora Boreali-Americana*, was made by Archibald Menzies (1754-1842), who had been a gardener at the Royal Botanic Garden, Edinburgh, prior to studying surgery. As a naval surgeon, Menzies had sent herbarium specimens and seeds of Nova Scotia plants for the Royal Botanic Gardens, Kew, to Banks in 1785, and had botanized in the vicinity of Nootka in 1787, on which occasion he discovered the type species of a genus of ericaceous shrubs that would later be named for him, *Menziesia ferruginea* Sm. However, it was as a member of Captain George Vancouver's *Discovery* expedition of 1791-1795, for which he had been selected as naturalist by Banks, that Menzies made his greatest contributions to botany. This expedition explored the Pacific coast from Alaska to Chile, giving particular attention to the channels and inlets of British Columbia, and also visited the Sandwich (now Hawaiian) Islands (Jepson 1929; Stearn 1988; Reveal 1992). The many species that Menzies discovered (some, of course, south of the Strait of Juan de Fuca) included the Western Red Cedar, *Thuja plicata* Donn ex D. Don (type locality Nootka Sound), the Douglas Fir, *Pseudotsuga menziesii* (Mirb.) Franco (type locality Vancouver Island), and the madroño, *Arbutus menziesii* Pursh.

Although many books and papers on North American plants appeared earlier, the first actual flora of any major part of the continent, published in 1803, was *Flora Boreali-Americana*, by André Michaux (1746-1803), a botanical explorer from France. Michaux's travels, which extended south to Florida and west to the [U.S.] Mississippi River, included a remarkable expedition into Canada in 1792. From Lake Champlain he went to Montréal, Québec City, and Tadoussac, thence via the Saguenay River to Lac Saint-Jean. He and his party then traveled north by canoe ca. 250 km to Lake Mistassini (Map 1), in the interior of northern Québec, and down the Rupert River (rivière des Goélands) for some distance to the west, before returning by the same route. The vicinity of Lake Mistassini is a calcareous enclave in the predominantly granitic Canadian Shield, and there Michaux discovered some disjunct populations of hitherto unknown taxa with generally more western ranges,

e.g., *Hedysarum alpinum* L. var. *americanum* Michx. and *Erigeron hyssopifolium* Michx., along with the attractive primrose, *Primula mistassinica* Michx., that he named for the lake. To this day Lake Mistassini remains remote and inaccessible by road, and there was no further significant botanical exploration of the interior of northern Québec until 1870. (On Michaux, see Ewan 1974 and many other publications cited by Stafleu and Cowan 1981; also Savage and Savage 1986 and Blondeau 1987; on his itinerary in Canada, see Rousseau 1948.) Thomas Nuttall (1786-1859, on whom see numerous references cited by Stafleu and Cowan 1981) was briefly in Upper Canada in 1809; he obtained several records from the vicinity of Niagara Falls for *The Genera of North American Plants*, but became ill in Ancaster and did no further botanizing in Canada.

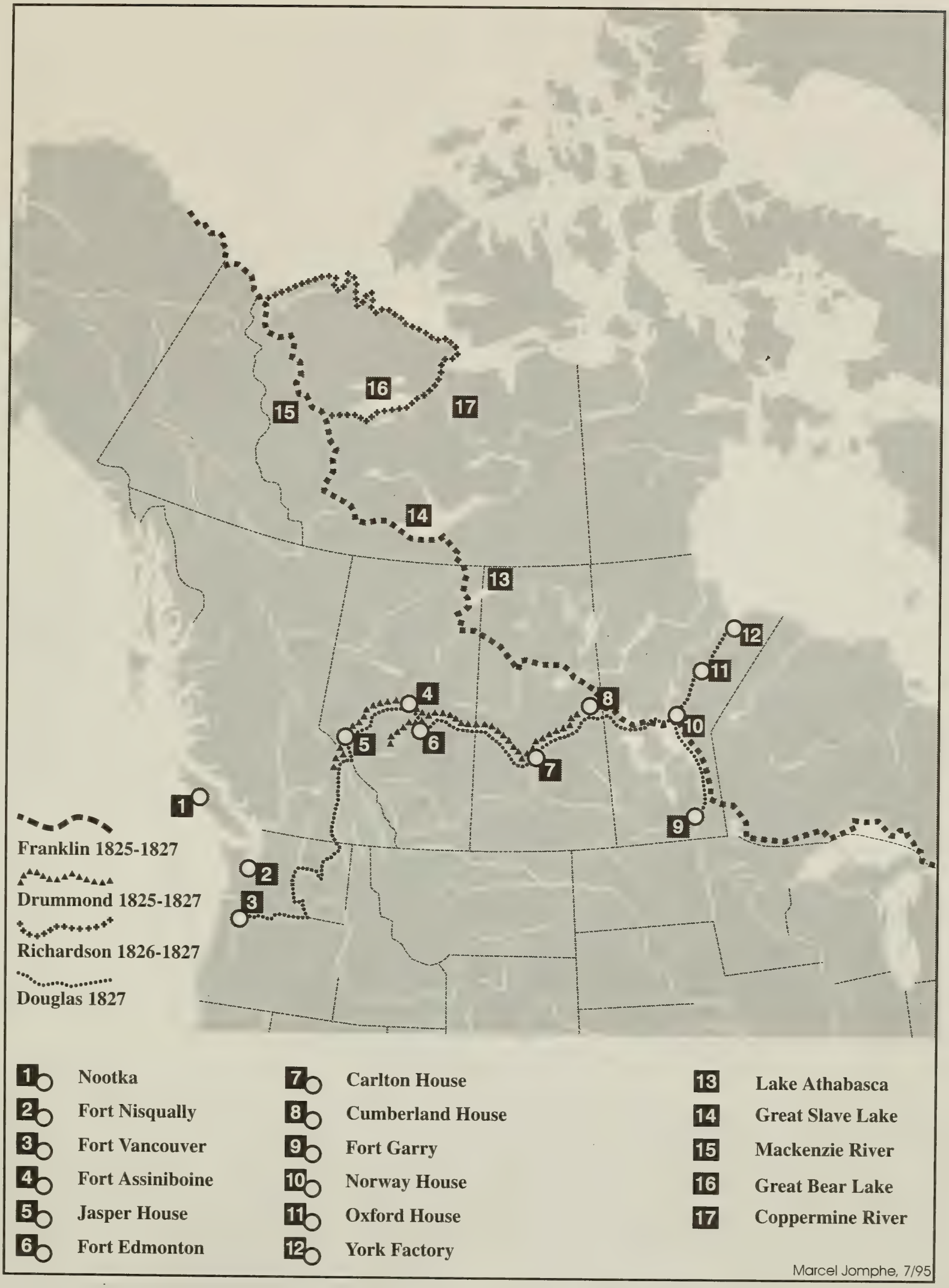
Yet another author of an important early North American flora also came to Canada, but *Flora Americae Septentrionalis* had already been published when its author, Frederick Pursh (né Friedrich Traugott Pursch, 1744-1820) arrived in Montréal in 1814. Pursh's health was deteriorating by this time, but he did quite a bit of botanizing in the vicinities of Montréal and Québec and in the Ottawa Valley, intending to write a flora of Upper and Lower Canada — one of many such abortive plans in the nineteenth century. He also visited the island of Anticosti in the Gulf of St. Lawrence in 1818. Some of Pursh's specimens from this period are extant, most of them from the herbarium of his patron, A. B. Lambert in England, others being duplicates from the herbarium of his friend William Sheppard (below). Pursh's own herbarium and his manuscripts were destroyed by fire, as was Sheppard's herbarium, which had contained many of Pursh's later collections (Ewan 1952; Savard 1976).

Arctic Exploration: The quest for the Northwest Passage

Malaspina's and Vancouver's voyages (above) were among the first of numerous exploring expeditions by several nations during the nineteenth century that were significant in the context of floristic knowledge. British expeditions, and later those from the United States, Norway, and Germany, included many to the Canadian Arctic. Berton (1988) dated the quest for "The Arctic Grail" — the Northwest Passage and the North Pole — from 1818 to 1909, and Levere (1993) selected the period from 1818 through 1918 for his coverage in his treatise on the scientific aspects of the exploration of the Canadian Arctic. There were many arctic expeditions during this period on which botanical specimens were secured and, in view of the heroism and dedication represented by these collections, it is regrettable that only the major ones can be noted here. Fortunately, a thorough account of botanizing in the Arctic from 1818 to 1909 was compiled by Simmons (1913), who listed 45 explorers and collectors, plus others who assisted, with the dates of their expeditions and the islands on which they obtained specimens. Polunin (1940) listed 102 botanical collectors in the Canadian Eastern Arctic (west to Cornwallis and Somerset islands, but thereby covering virtually all botanically significant Canadian Arctic exploration to that time) from 1792 through 1938, and Porsild (1964b) continued the account through 1961. A thorough history of the floristic exploration of the mainland portion of the Northwest Territories was published by Porsild and Cody (1980). (For general accounts of the expeditions noted below, with biographical sketches of many of the principals, see Berton 1988 and Levere 1993; for brief but botanically oriented notes on the plant collectors, see Desmond 1994.)

The first arctic expedition to collect significant numbers of botanical specimens was John Ross's expedition to Baffin Bay in 1818 (Map 3). On board to make scientific observations, upon recommendation by Banks, was Edward Sabine (1788-1883). This was followed by three expeditions led by (William) Edward Parry (1790-1855), who had been Ross's second-in-command. Of these, the most significant to botany was the first, in 1819-1820 (Map 3). The plants collected on Melville Island by Parry and other officers, again including Sabine (see Simmons 1913, Polunin 1940, and Grant 1994 for names of others) were described by Robert Brown (1773-1858; of London) (Brown 1823), who had also published upon the Baffin Island plants from the Ross expedition (Brown 1819). Brown's (1823) *Chloris Melvilliana* was the first major paper on the plants of the Arctic Archipelago, and included descriptions of many new taxa (Mabberly 1985; Grant 1994). The genera new to science that are still generally accepted at that rank were *Dupontia* R.Br. and *Pleuropogon* R.Br., both in the Poaceae, and *Eutrema* R.Br. and *Parrya* R.Br. in the Brassicaceae. Parry's second expedition obtained plants from the Melville Peninsula and from Southampton and Baffin islands in 1821-1823 (Map 3), most of which were collected by George Francis Lyon (1765-1832). Parry's third expedition in 1824-1825 brought back specimens from Somerset, Devon, and Baffin islands. The botanical reports of these expeditions were written by W. J. Hooker (1825, 1826). (On these expeditions see M. J. Ross 1994.)

There followed John Franklin's two land expeditions to the Arctic shore. On both, John Richardson (1787-1865) served as surgeon and naturalist, having been recommended by Banks. Richardson has been



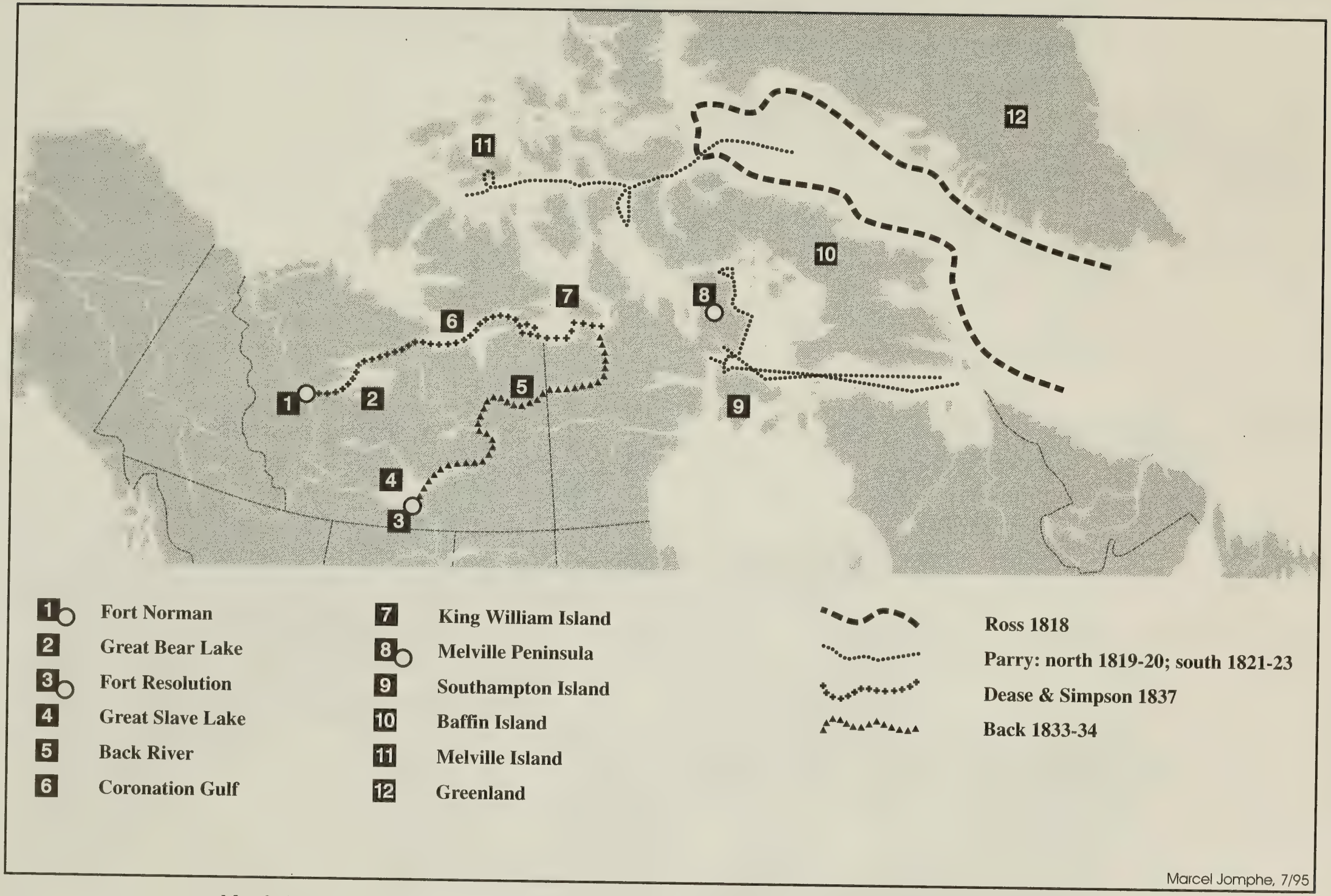
Map 2. Routes of the expeditions most significant as sources of specimens from British North America studied by Sir William Jackson Hooker during the preparation of his *Flora Boreali-Americana*.

described by Houston (1985) as "already a remarkably competent botanist, able to identify a prodigious number of known species in a totally new region" and also to recognize "many other plants as new and hitherto undescribed species." On the expedition of 1818-1822, Franklin's party traveled west from York Factory on Hudson Bay via rivers and portages to the Hudson's Bay Company's Cumberland House on the Saskatchewan River, where they spent the first winter. Richardson made a trip the next spring to Carlton House on the North Saskatchewan River (near present-day Carlton, Saskatchewan), where he discovered *Phlox hoodii* Richardson, which upon his return to Britain he named for a member of the expedition who was murdered on the Arctic shore. The party's route was then via Athabasca Lake, Great Slave Lake, and the Coppermine River to Coronation Gulf and the Kent Peninsula. In the Arctic, this expedition, being inadequately equipped, encountered disaster, and eleven men perished from cold and starvation (Richardson's journal, edited by Houston 1985). Many of the scientific collections were jettisoned, but specimens sent back early in the expedition were described in the botanical appendix to the expedition report. New species among them account for the authorship "Richards." or "Richardson" often encountered in floras; they included *Cypripedium passerinum* Richardson and *Ribes hudsonianum* Richardson.

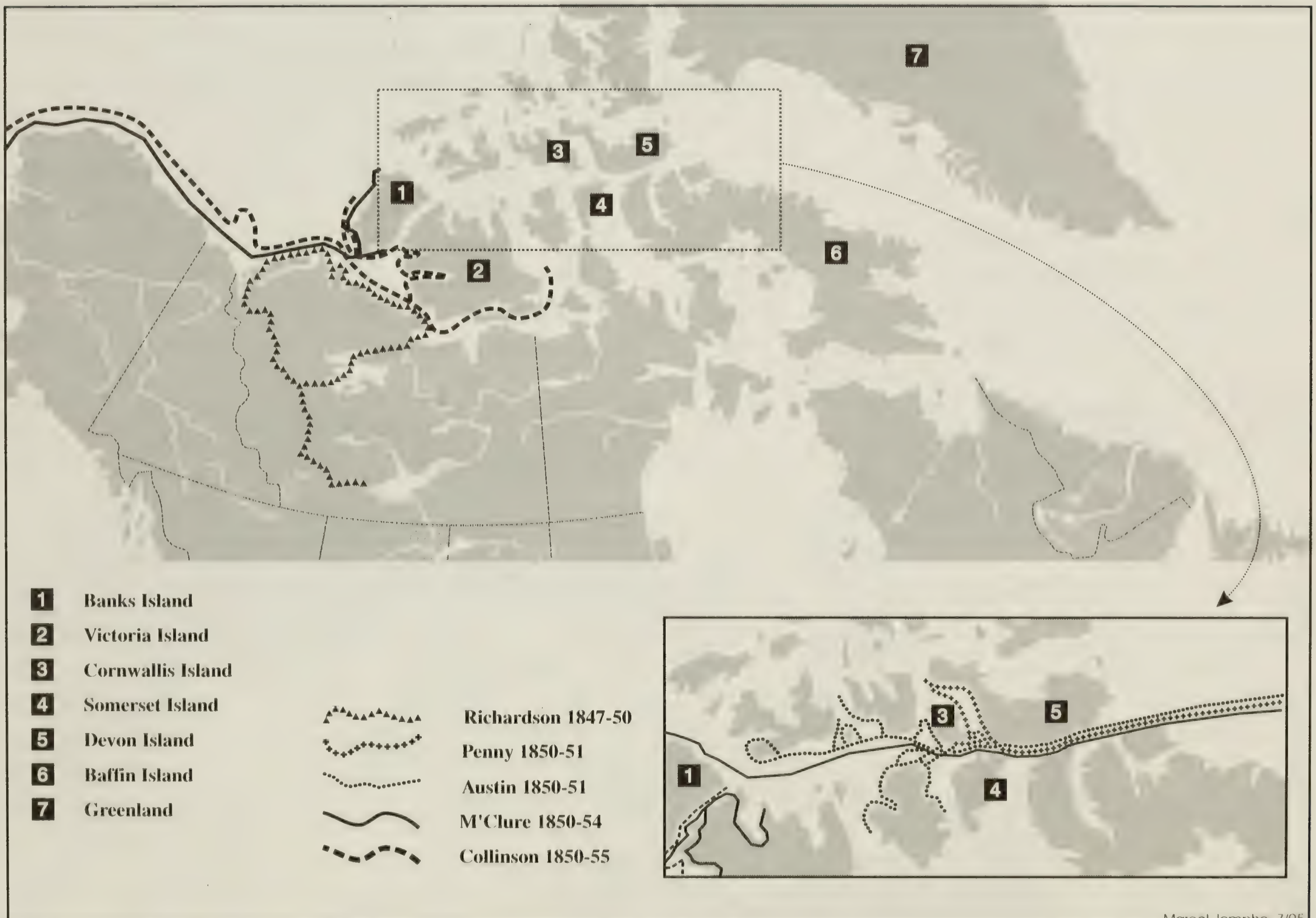
Franklin's second expedition was scientifically a great success. Botanizing began at Lake Simcoe in the spring of 1825 and continued until the party returned to Lachine in the autumn of 1827. The route was by canoe along the north shore of Lake Superior and via Lake Winnipeg north to Grand Rapids; thence by several rivers to Lake Athabasca and Great Slave Lake; and down the Mackenzie River to its delta (Map 2). Franklin then went west along the Alaskan coast and returned to Great Slave Lake via the Mackenzie; Richardson went east along the Arctic shore to the mouth of the Coppermine River and returned to the Mackenzie via Great Bear Lake. Another member of this party who participated in the botanizing was George Back (1796-1878), who in 1833-1834 led an expedition along the Great Fish (now Back) River, on which many plants were collected by Richard King (ca. 1811-1876) (Map 3). This expedition was a major source of specimens of boreal and arctic plants for study and citation by Hooker. One of Richardson's discoveries in 1826 that Hooker found especially attractive was *Phlox richardsonii* Hook., a rare species of restricted distribution in the western North American Arctic. (Information on Richardson's itinerary has been obtained primarily from Houston 1985. Numerous publications on the Franklin expeditions and on Richardson have been cited by Stafleu and Cowan, 1976, 1983, and on Richardson, Back, and King by Desmond 1994.)

From New York to Cumberland House, this party included Thomas Drummond (ca. 1793-1835, on whom see Coats 1969; Hoeniger 1987; Nelson 1990; and publications cited by Stafleu and Cowan 1976 and Desmond 1994). Drummond remained in the vicinity of Cumberland House until August 1825, when he traveled with a Hudson's Bay Company brigade via Fort Edmonton and Fort Assiniboine to the upper waters of the Athabasca River. From October 1825 until the following spring, Drummond stayed "alone, without books, subsisting on the game that he shot" by the Baptiste River northwest of Rocky Mountain House. In the spring he went to Jasper House, and that summer he botanized in the foothills between Jasper House and the Peace River. In the autumn of 1826 he accompanied another H.B.C. brigade across 1748-m Athabasca Pass in the Rockies and down the Wood River to the northernmost bend of the Columbia River, the site called Boat Encampment until it was flooded by Mica Dam. He recrossed the divide and went to Fort Edmonton for the winter, then proceeded downstream to Carlton House in the spring of 1827. Drummond collected several thousand herbarium specimens on this expedition, a good number of them representing species new to science, including *Dryas drummondii* Richardson ex Hook., *Potentilla drummondii* Lehm., and *Gentianella propinqua* (Richardson) J. M. Gillett. (The best-known species named for Drummond, *Phlox drummondii* Hook., was one of his later discoveries in Texas.) He also collected seeds for botanical gardens in Scotland and Ireland; some of his discoveries were raised by himself in the garden of the Belfast Botanic and Horticultural Society, of which he became founding curator shortly after his return from North America. Many of his herbarium specimens were mosses, of which he assembled sets of exsiccatae. Hooker named the moss genus *Drummondia* for him, based on a species Drummond had encountered in the Rockies, and stated that "the whole...of North America [had] not been known to possess so many mosses as Mr. Drummond detected in this single journey."

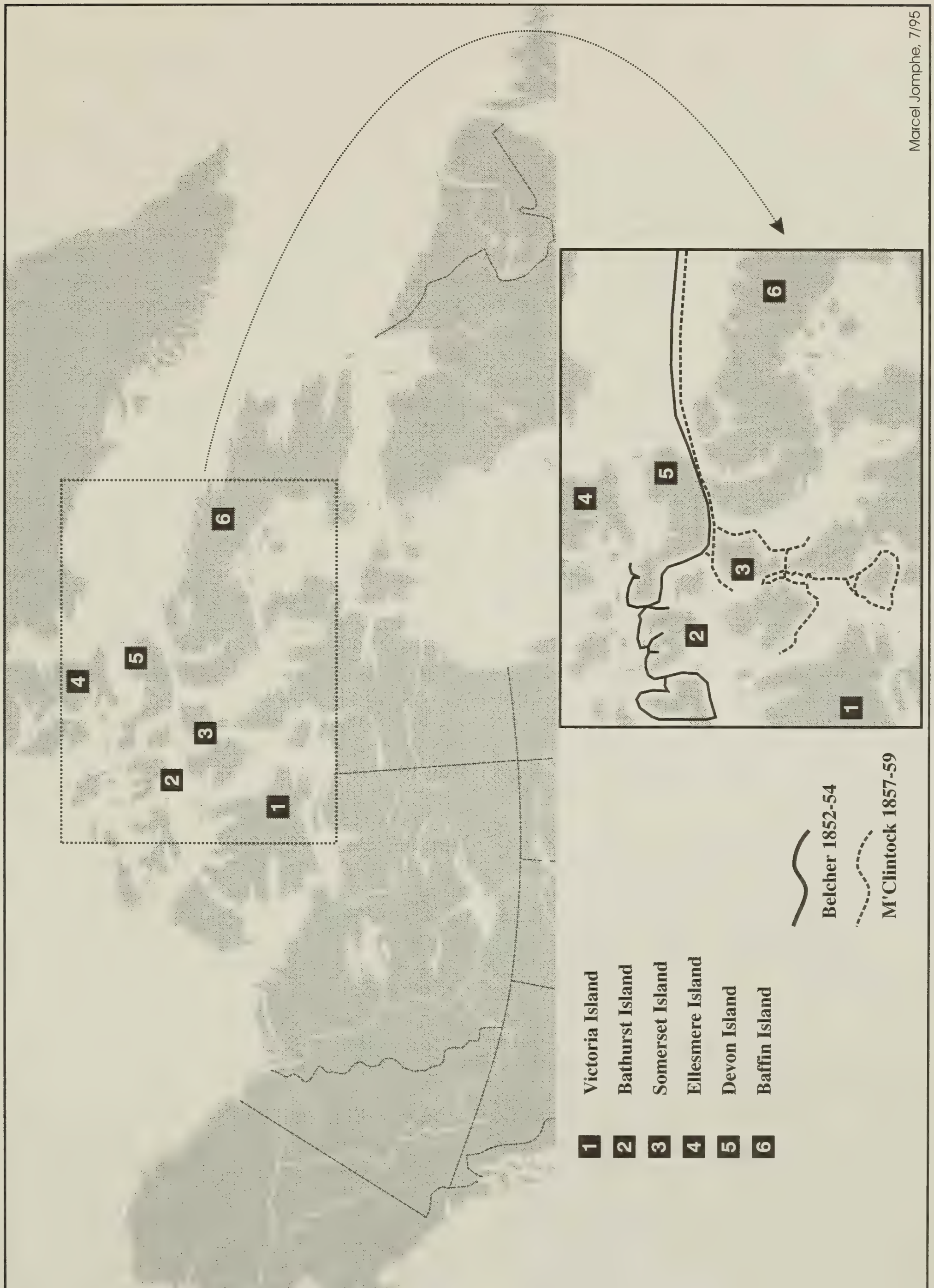
Whereas those discussed above were all Royal Navy expeditions, the next of note botanically was sponsored by the Hudson's Bay Company. In 1837-1839, H.B.C. men Peter Warren Dease (1788-1863) and Thomas Simpson (1808-1840) crossed Great Bear Lake and proceeded to Coronation Gulf, thence along the coast to the mouth of the Castor and Pollux River east of King William Island, and back by much the same route (Map 3) (Newman 1985; Berton 1988). Botanical specimens were also brought back on whaling vessels. The largest lot of specimens from Baffin Island during the nineteenth century was that collected by James Taylor (1823-1913), a surgeon on a whaler.



MAP 3. Routes of botanically significant expeditions in subarctic and arctic British North America, 1818-1834.



MAP 4. Routes of botanically significant expeditions in arctic British North America, 1847-1855.



MAP 5. Routes of botanically significant expeditions in arctic British North America, 1852-1859.

It is well known that Franklin's third expedition ended in tragedy. The "Great Search" for evidence of its fate, involving many men and ships, contributed much to the knowledge of the Arctic. The first search expedition, from 1847 to 1850, was led by Richardson (Map 4), with another scholarly surgeon-naturalist, John Rae (1813-1893, on whom see Newman 1985 and Richards 1990), as second-in-command; these explorers collected the first plant specimens from Victoria Island. Unlike the others noted in this context, this expedition started from Great Slave Lake rather than coming by ship via Baffin Bay or the Bering Strait. Botanically significant expeditions during the peak years of the search, 1850 to 1855, included those of Horatio T. Austin, 1850-1851 — specimens from Devon, Baffin, and other islands, collected principally by David Lyall (1817-1895); William Penny, 1850-1851 — the first specimens from Cornwallis Island, obtained by Peter Cormack Sutherland (1822-1900); Robert J. LeM. M'Clure, 1850-1854 — the first specimens from Banks Island and also some from Victoria Island, collected by Johann August Miertsching (1817-1875), a Moravian missionary from Labrador, who had been recruited as an interpreter; Richard Collinson, 1850-1855 — specimens from the same islands, collected by Robert Anderson (1818-1856); and Edward Belcher, 1852-1854 — specimens mostly from Baffin and Devon islands, Lyall again having been the naturalist. Later, on Francis Leopold M'Clintock's expedition of 1857-1859, supported by Lady Franklin after the Royal Navy had given up the search, specimens from Baffin and Somerset islands were obtained by the expedition's surgeon-naturalist, David Walker (1837-1917) (Maps 4 and 5). It was J. D. Hooker (1857, 1861) who reported most of the botanical discoveries from this period.

The next expedition to make a major floristic contribution was the British Polar Expedition of 1875-1876, commanded by George S. Nares. The principal collector of botanical specimens, and the author of the botanical report (Hart 1880), was Henry Chichester Hart (1847-1908), who found 77 species on northern Ellesmere Island. The same island was a destination of the Second Norwegian Arctic Expedition of 1898-1902, under Otto Sverdrup, which also visited Devon Island and Greenland. The expedition botanist, Herman Georg Simmons (1866-1943, on whom see Dahlgren 1944), wrote his doctoral dissertation (Simmons 1906) on the plants he found on Ellesmere Island, and later (Simmons 1913) discussed at greater length the phytogeography of the Canadian Arctic Archipelago. (Several of these expeditions also contributed significantly to the floristic knowledge of Greenland; see Pringle 1995b: 364, 365, 367.)

Rodgers' (1944) brief mention of plants from Grinnell Land (Ellesmere Island) does not convey the poignancy of the circumstances under which Asa Gray acquired the specimens listed in one of his last papers. Most of the specimens collected by members of Adolphus Washington Greely's party were lost, but Greely's personal collection of plants was found when the survivors of this tragic expedition were rescued in 1884.

Toward the close of this epoch in the history of arctic exploration, the polar expeditions led by Robert E. Peary of the United States also contributed to floristic knowledge, although more significantly in Greenland than in Canada (see Pringle 1995b: 367). Most notably, botanical specimens were obtained from the east coast of Baffin Island by the geologists (Charles) David White (1862-1935) and Charles Schuchert (1858-1942, on both of whom see Ewan and Ewan 1981 and references cited therein) in 1897 (Holm 1900).

One additional expedition, which was unquestionably successful, deserves mention before closing this section on arctic exploration. Roald Amundsen forwent the glory of bringing his sloop *Gjøa* through the Northwest Passage in a single season in order that more scientific observations could be made. Numerous botanical specimens, mostly from King William Island, were obtained during the years 1903 through 1906, the principal collector being Adolf Henrik Lindström (1866-1939). These plants were listed by the Danish botanist Carl Emil Hansen Ostenfeld (1910).

The Hooker Era: Contributions toward the *Flora Boreali-Americana*; Horticultural expeditions

While the earliest of these exploring parties were in the Arctic, some major horticulturally oriented expeditions did, albeit belatedly, take place in Canada. John Goldie (1793-1886) spent some time in the Lower Great Lakes and Lake Simcoe regions in 1819, in quest of both horticultural and herbarium specimens (Pringle 1989 and references cited therein). In 1823 the Horticultural Society of London (now Royal Horticultural Society) sent David Douglas (1798-1834) to North America. Douglas spent most of his time that year in the United States, but he also explored Upper Canada at Niagara Falls and in the area from Amherstburg to Lake St. Clair. Two years later the Horticultural Society sponsored Douglas on a much greater expedition, with logistic support provided by the Hudson's Bay Company. In March 1827, after two years in present-day Washington and Oregon, Douglas began a trek across the northern portion of the Oregon Territory (now British Columbia) and the interior of British

North America (Map 2). From Fort Vancouver (now Vancouver, Washington), he traveled up the Columbia River to Boat Encampment, thence via the Wood River and overland to Athabasca Pass, which he reached 2 May. From the pass he went to the Athabasca River at Jasper House; then by that river to Fort Assiniboine, where he did considerable botanizing. His route was next to Fort Edmonton, from which he followed the North Saskatchewan River to Carlton House, where he met and botanized with Drummond. Downstream, at Cumberland House, he joined Richardson, as well as Drummond, who had preceded him. At Norway House, at the northern end of Lake Winnipeg, Douglas spent 17 days "overhauling his collections." There his party was joined by Franklin, with whom he traveled to Fort Garry (now Winnipeg). Douglas returned to Norway House and continued northeast to Oxford House, where he collected more plants, and down the Hayes River to the Hudson's Bay Company's York Factory, which he reached 28 August 1827 and from which he sailed for England on a whaling vessel (Coats 1969; Davies 1980; Waldron 1986; Reveal 1992; see also publications on Douglas cited by Stafleu and Cowan 1976).

Douglas's sponsors were well rewarded by the results of this expedition. Numerous introductions to British horticulture have been listed by Davies (1980), including *Pseudotsuga menziesii* (Mirb.) Franco (hence its common name, Douglas Fir). Only a few species new to science were discovered by Douglas on the Canadian portion of this expedition. He had already obtained the type specimens of the names of some new species in Washington and Oregon, and specimens of other species that he encountered had already been collected by Menzies and by Lewis and Clark. (It was in California in 1831 that he discovered most of the species that now bear the epithet *douglasii*.) One discovery that did come from present-day Canada was the type species of the genus in the Primulaceae named for Douglas by John Lindley, *Douglasia nivalis* Lindl., found near the headwaters of the Columbia River at ca. 3650 m. This was, moreover, the first botanical exploration of the vast regions between coastal British Columbia and the Rocky Mountains, and the last of major significance until John Macoun's expeditions began in 1872.

On the ship and while botanizing on the Washington and Oregon coasts, Douglas had been accompanied by another accomplished naturalist, John Scouler (1804-1871). After Douglas had traveled up the Columbia River to Fort Vancouver, Scouler continued his exploration of the coast, mostly south of the present boundary but on one excursion in 1826 north to the Queen Charlotte Islands and Observatory Inlet, near the southern boundary of Alaska, stopping at many harbours, and returning via Nootka (McKelvey 1956). As was appropriate in the temperate rain forest, Scouler gave considerable attention to bryophytes, and among his specimens from Observatory Inlet was the nomenclatural type of a species of moss, *Scouleria aquatica* Hook., named for him by Hooker. (It may be mentioned here that although William Fraser Tolmie [1812-1886], a noted botanical explorer in western North America during the 1830s and 1840s, was employed by the Hudson's Bay Company and spent his latter years in Victoria, British Columbia, virtually all of his plant collecting was done south of the present boundary, when he was based at Fort Vancouver and Fort Nisqually [now, respectively, Vancouver and Tacoma, Washington] [McKelvey 1956 and other publications cited by Stafleu and Cowan 1986].)

Another expedition with a horticultural emphasis was organized by Robert Brown (ca. 1767-1845), a nurseryman of Perth, Scotland, who wanted to see in their native habitats some of the North American species that had become popular in British gardens. With him was James McNab (1810-1878), then superintendent of the Caledonia Horticultural Society's garden, later to distinguish himself as curator of the Royal Botanic Garden, Edinburgh. In 1834, after stopping briefly at Saint John, New Brunswick, and several Canadian ports on the St. Lawrence River and Lake Ontario, Brown and McNab began their overland journey through Upper Canada at Niagara Falls and proceeded northwest to the port of Goderich on Lake Huron, from which they sailed south to continue their journey in the United States. McNab collected "many hundreds" of herbarium specimens as well as horticultural material and wrote several papers on their discoveries. He reported prairie species near Brantford (now largely extirpated from these eastern populations) and noted some of the characteristic species of the beaches and dunes of the Lake Huron shore (Macnab [sic] 1835; Nelson and Dore 1987; Pringle 1989; and publications on McNab cited by Desmond 1994).

It is appropriate next to focus attention on William Jackson Hooker, already mentioned above. Hooker was a promoter of floras for all parts of the British Empire, and after writing the botanical reports for Parry's and other expeditions, he became especially interested in the plants of British North America. His commission to prepare the botanical appendix for the report of Franklin's second expedition crystallized his determination to write the *Flora Boreali-Americana* (Hooker 1829-1841). This served as the standard flora for present-day Canada for many years, and the importance of individuals in the history of the floristic exploration of Canada during the early nineteenth century is largely proportionate to the number of their specimens cited by Hooker.

Among the specimens to which Hooker had access were those collected by Banks, Douglas, Drummond, Goldie, Kohlmeister, McNab, Menzies, Parry, Pursh, Sabine, Scouler, and, of course, the first two Franklin expeditions. He was also aware of lists of Newfoundland plants compiled by Auguste-Jean-Marie Bachelot de la Pylaie (1786-1856), who had botanized on that island in 1816 and 1819-1820 (Leroy 1957; South 1980).

Hooker also solicited specimens for this project — very successfully, as he was a genial man, who acknowledged contributions with gifts of books and prints and took care to give credit where due in his publications. Also, although his own fortune was considerably diminished by this time, his social background was such that he was acquainted with many of the military officers, ambassadors, and government officials who might be appointed to positions in British North America. Natural-history "cabinets" and private herbaria were already popular in British society, but undoubtedly some of the plant collectors whose names appear in the *Flora Boreali-Americana* were recruited to the cause by Hooker.

Sir Alexander Forrester Inglis Cochrane (1758-1832), best known to history as the leader of the attack on Washington, D.C., in 1814, contributed only a small number of specimens himself, but it appears that while visiting his son, who was Governor of Newfoundland, he recruited Hooker's principal source of specimens from that island. Mary Brenton collected many specimens from the vicinity of St. John's and from other localities to which she accompanied her father, a supreme court justice, on the travels required by his judicial duties. She in turn enlisted the efforts of John Winter (ca. 1805-1891), a Scottish-educated physician at Greenspond (later in politics), who contributed specimens from his far-flung practice; and also one or more women among the "livyeres" (permanent residents of British descent) of Labrador when they visited St. John's (Brenton-Hooker correspondence, Royal Botanic Gardens, Kew). Another important contributor of specimens from Newfoundland and also from Labrador was Robert Morrison (d. 1825), a naval surgeon (Pringle 1982). Specimens from the interior of Newfoundland, which hitherto had remained largely unknown to the white settlers, were obtained from two expeditions by William Eppes Cormack (1796-1868, on whom see Story 1976) in 1822 and 1827. Specimens from coastal Newfoundland were also among those that Cormack sent to the Linnean Society of London.

Hooker saw few specimens from the Maritime Provinces. As noted above, Menzies had collected some in Nova Scotia. Hooker's only source of New Brunswick plants was Edward Nicholas Kendall (1800-1845, on whom see Holland 1988), a veteran of Franklin's second expedition, who had become commissioner of a land company in Fredericton.

Many of Hooker's specimens from Lower Canada (now that part of Québec south of the Hudson Bay-St. Lawrence divide) were sent to him by the chatelaines of estates near Québec City, the administrative center for the British provinces in eastern North America. One was the Countess of Dalhousie, née Christian Broun (1786-1839, on whom see Nelmes and Cuthbertson 1932 and Pringle 1995), whose husband, George Ramsay, the ninth earl, was Governor-in-Chief of British North America from 1820 to 1828. Another was her neighbor in Sillery, Anne Mary Perceval, née Flower (1784-1876, on whom see Pringle 1986), wife of the collector of customs for Québec, another member of Lower Canada's powerful "Château Clique." Their large estate, Spencer Wood, included impressive gardens as well as woodlands from which some of the botanical specimens were obtained. Also in this coterie were William Sheppard (1784-1867, on whom see Savard 1976), a Québec businessman, and his wife, née Harriet Campbell, who also contributed specimens from the vicinity of Québec City and eastward along the St. Lawrence. The Sheppards were especially active in the Literary and Historical Society of Québec, in whose *Transactions* as well as other journals both published papers on natural-history topics (note especially Sheppard 1831, 1837).

In Montréal Hooker had a valuable correspondent in Robert Cleghorn, who since 1810 had operated a nursery, Blink Bonny Gardens, on a site now opposite the main entrance to McGill University. Cleghorn, who provided a home for Pursh during the latter's last illness, is believed to have been Canada's second commercial nurseryman, and his crabapple selections, at least one of which is still in cultivation, are believed to have been the first cultivars of any genus to have been selected and named in Canada.

One of Hooker's most important sources of specimens from Upper Canada — Brown and McNab's expedition — has already been noted. Another major contributor was Clement Charles Todd (ca. 1795-1828, on whom see Pringle 1986-1988), a surgeon at the Naval Establishment at Penetanguishene on Georgian Bay. When the officers of Franklin's second expedition arrived at Penetanguishene in the spring of 1825, Richardson told Todd, who was already active in natural history, of Hooker's desire for botanical specimens from British North America. Some of Todd's specimens represented rare species of the dune-panne complexes, including the nomenclatural type of *Linum medium* (Planch.) Britton. Smaller quantities of specimens from Upper Canada seen by Hooker included those collected by Douglas, a few obtained by his Québec correspondents on visits to Kingston, and some sent by botanists from New York who had visited the Canadian side of Niagara Falls.

Three others active during the same period should be mentioned, although their specimens were not cited by Hooker. Andrew Fernando Holmes (1797-1860, on whom see Raymond 1954 and Bensley 1985), a Montréal physician, founded a medical school in 1823, which six years later became part of McGill University, His courses included botany until 1845, and he amassed a large herbarium, which he donated to the university in 1856. He began this herbarium in Scotland and acquired specimens from diverse regions through exchanges, but its greatest significance was in Holmes's own collections from the vicinity of Montréal. Some of Holmes's records, as well as specimens sent to Torrey by Mrs. Perceval and the Sheppards, were cited by Torrey and Gray (1838-1843) in *A Flora of North America*.

Titus Smith, Jr. (1768-1860, on whom see Clark 1954, Gorham 1955, and Punch 1988), was commissioned by the Governor of Nova Scotia to survey the resources of the interior of that province (see Clark 1954, for maps of Smith's itineraries). Belatedly he has been recognized for his "insight into the pattern and process of vegetation development far in advance of his time" (Gorham 1955) and for his similarly enlightened views on conservation. Smith (1830) published a one-page list of "the principal indigenous plants of Nova Scotia," followed by a more extensive treatise on Nova Scotia's vegetation, economically important native species, and agricultural potential (Smith 1835). In 1833 he was commissioned to prepare specimens, including plants, for the museum of the Halifax Mechanics' Institute. No herbarium specimens collected by Smith are known to be extant, nor is it certain that any ever existed. Because Smith did not participate in the exchanges of specimens that united many botanists during the nineteenth century, his studies were not represented in the works of Hooker, Torrey and Gray, or Macoun.

James Robb (1815-1861, on whom see Bailey 1898 and Young 1986) came from Scotland to Fredericton in 1837 as the first faculty member in chemistry and natural history at King's College, the predecessor of the University of New Brunswick (not to be confused with King's College in Nova Scotia). Although primarily interested in geology, he began collecting specimens of the native flora shortly after his arrival, establishing, according to Boivin (1980), the earliest institutional herbarium extant in Canada. Robb did not publish on botanical subjects, but he did exchange specimens with Hooker (although not in time for citation in the *Flora Boreali-Americana*) and J. H. Balfour in Scotland.

After the Act of Union, 1841: Establishment of Canadian scientific institutions; Avocational botany becomes popular

Although Robb's activity in New Brunswick was an exception, the quarter-century following Brown and McNab's travels and Smith's investigations was, on the whole, a quiescent period in British North American botany, in striking contrast to the activity in the United States (see reviews by Ewan 1969; Stuckey 1978; papers reprinted in the latter work; also pertinent comments in Shinners 1962). South of the border John Torrey was at the peak of his career during this period, and the first edition of Gray's *Manual* was published; botanists were at work in every part of the country — Increase A. Lapham and John L. Riddell in the Midwest, H. B. Croom in Florida, and Albert Kellogg in California, to name but a few; and many regional floras were written, some describing new species. The different situation north of the border is illustrated, for example, by the history of the Lake Huron basin of Upper Canada, in which there appears to have been no botanical collecting whatever between 1834 and 1857 (Pringle 1989). Much of what botanizing did occur in British North America during this period, moreover, was done by visitors or short-term residents. Notable in this context was (Jean) Louis (Rodolphe) Agassiz's expedition to the north shore of Lake Superior in 1848, on which plants collected by Harvard student Charles Greely Loring, Jr. (1828-1902), provided many significant range extensions later to be cited by his brother-in-law, Asa Gray (Voss 1978). Also, Philip Whiteside Maclagan (1818-1892, on whom see publications cited by Desmond 1994), a British army surgeon, published a paper (Maclagan 1850) on plants he had encountered while stationed at Amherstburg and along the Rideau Canal between Kingston and Bytown (now Ottawa) during the 1840s. Maclagan wrote a manuscript flora of Canada (in the 1840s sense), but this was never published.

Several factors contributed to this difference. In the United States, the desire for universities and museums spread from the major cities of the eastern seaboard to the newly and sparsely settled trans-Appalachian regions. The cities of eastern British North America were smaller, with fewer cultural institutions of their own, and during this period there was little migration from these cities to other parts of present-day Canada. Also, after the American Revolution, the people of the United States could no longer identify with the cultural institutions of the British Isles; they had to establish their own. No such need was perceived in British North America, and sometimes there was actual disdain in high places. For example, when Charles Fothergill, William "Tiger" Dunlop, and John Rees proposed a number of cultural amenities for Upper

Canada in 1833, including a museum, a botanical garden, and a Literary and Philosophical Society, the Rev. John Strachan, whose influence was far disproportionate to his position as Church of England rector of York, stated of the last-named proposal that "such a society would scarcely be required in Upper Canada for another hundred years" (Baillie 1944; Anglin 1992: 102-109; Zeller 1987: 22, 198). Until 1841, the governors and lieutenant-governors were appointees from England, as were many members of the "Château Clique" and its Upper Canadian counterpart, the "Family Compact," in alliance with whom they held power; often they neither identified with Canada nor remained there long. Dates on escutcheons notwithstanding, British North America acquired its first university in 1802, when King's College, at that time a small Church of England school in Windsor, Nova Scotia, audaciously assumed this status. The first university classes in Canada West, which Upper Canada had by then become, met in 1841 at Victoria University in Cobourg and in 1842 at Queen's University in Kingston. Despite statements of broader purposes in their charters, these universities, as realistically viewed, were "not founded in order to advance the state of knowledge...[but] to promote the cause of denominational religion" (McKillop 1983), and their growth was very slow. In Canada East (formerly Lower Canada), McGill University began classes, other than those of Holmes's medical school, in 1843. (For an extensive discussion of government, society, and related topics as they affected scientific pursuits in Canada during the period from 1835 to 1860, see Zeller 1987 and references cited therein.)

Although the rebellions in both Lower and Upper Canada in 1837 were quelled, "responsible government" soon thereafter supplanted the power of the Crown appointees and Strachan's minority denomination. The United Province of Canada, formed in 1841 from Upper and Lower Canada, provided more support for scientific studies and expeditions and eventually for secular higher education.

Floristic exploration of Canada gradually picked up during the 1850s. Henry Holmes Croft (1820-1883), professor of chemistry and related subjects at King's College in Toronto (Church of England until secularized in 1850 as the University of Toronto; not to be confused with the schools in Nova Scotia and New Brunswick), collected some botanical specimens that became the nucleus of the university's herbarium, now at the Royal Ontario Museum (Forward 1977). In 1853, the university employed William Hincks (1794-1871, on whom see Wilson 1972 and other references cited in Pringle 1989; also Zeller 1987, particularly for comments on Hincks's beliefs on creation and classification), from Cork, Ireland (and brother of the Premier of Canada), as the first professor of natural history in its college of arts. (Botany was already represented in the medical faculty and in the early, short-lived agricultural faculty, under George Buckland [1804-1895].) Hincks began floristic studies that lasted, at least desultorily, until ca. 1870. He was one of at least nine individuals between 1850 and 1900 who announced plans for a flora of Canada, but, in part because his attention was divided among many diverse fields, his actual contributions to floristic knowledge were far more modest. Rare ferns of the Niagara Escarpment near Owen Sound were among his most significant floristic discoveries (Pringle 1989).

Following Holmes, James Barnston (1831-1858, on whom see Zeller and Noble 1985 and Zeller 1987) taught botany at McGill University. Barnston, a physician who had studied botany under J. H. Balfour in Edinburgh, was the first faculty member at a Canadian university to be designated professor of botany. He had ambitious plans for studies of the Canadian flora and expansion of the university herbarium, but he did not live long enough to contribute greatly to Canadian botanical exploration. The botanical club that he founded at Montréal did not long survive him (Penhallow 1897; Boivin 1980; Zeller 1987). Barnston was succeeded by Sir (John) William Dawson (1820-1919), a renowned paleobotanist although an anti-evolutionist; later, botany was taught by David Pierce Penhallow (1854-1910). Being primarily interested in other branches of botany, neither Dawson nor Penhallow contributed greatly to floristic exploration, but students' collections submitted over the years occasionally included specimens from poorly botanized areas (Pringle 1989).

Meanwhile, in Scotland, David Douglas's work in western British North America had inspired a private association interested in new plants for Scottish gardens to sponsor another expedition. John Jeffrey (1826-1854), who had been recommended by McNab, arrived at York Factory on Hudson Bay in August 1850, and accompanied Hudson's Bay Company parties, reversing Douglas's route, to the Columbia River. Thence he went to southern present-day British Columbia, where he spent most of 1851 and 1852, and ultimately to California. Like Douglas, Jeffrey obtained most of his seeds and botanical specimens south of the present border, but his herbarium specimens included significant numbers from Vancouver Island and from Fort Langley, Fort Hope, and other localities in the lower Fraser valley (McNab 1873; Johnstone 1939). Another private organization sponsored the "British Columbia Expedition" of 1863-1866, on which Robert Brown (1842-1895; b. Campster, not the Brown who had accompanied McNab) collected herbarium specimens as well as horticultural material (McNab 1873).

In England, John Palliser, a sportsman and explorer in the Victorian tradition, secured backing from the Royal Geographical Society and the Imperial government for his British North American Exploring Expedition (on which see Spry 1963). The botanical collector was Eugène Bourgeau (1813-1877, on whom see Raymond 1957, 1972), who subsequently botanized extensively in México. For two years, until Bourgeau left the party in the spring of 1859, the Palliser expedition explored the forests between Lakes Superior and Winnipeg; crisscrossed the prairies, as far north as Fort Assiniboine and south into present-day Montana; and traversed the Rockies and discovered Kicking Horse Pass (for map see Spry 1963). Bourgeau obtained about 60 000 herbarium specimens representing about 1200 species. Ordinarily, Bourgeau's locality data were excellent for his time. However, although these specimens came from five present-day provinces and from the St. Lawrence, Arctic, and Pacific watersheds, all data were replaced with the single word "Saskatchewan" when the labels were prepared at Kew, thereby eliminating the significance of Bourgeau's North American specimens in phytogeographic studies (Raymond 1957, 1972).

In 1859-1860 Robert Kennicott (1835-1866, on whom see Zochert 1980) of the Chicago Academy of Science traveled from Great Slave Lake via the Liard, Mackenzie, and Peel rivers and across the height-of-land to the Yukon River, which he descended to Fort Yukon, Alaska. The botanical specimens obtained on this trip were the first from the present Yukon Territory (Hultén 1940; Porsild and Cody 1980). Kennicott also led an expedition to Saskatchewan and another to British Columbia, the Mackenzie River, and west to Alaska during the 1860s. Participants in his British Columbia expedition of 1865 included Joseph Trimble Rothrock (1839-1922, on whom see Stafleu and Cowan 1983, and references cited therein), an American just beginning a distinguished career in botany and forestry. Rothrock's specimens, however, were lost in an accident on the Fraser River on the return trip (Rodgers 1944; Ewan and Ewan 1981; Stafleu and Cowan 1983).

The United Province of Canada established its Geological Survey in 1842. Its mandates were primarily in cartography and in the exploration of mineral resources, but were soon extended to include many aspects of natural history (Alcock 1948; Waiser 1989). Its first expeditions of major botanical significance were led by Robert Bell (1841-1917, on whom see Ami 1927). Bell, who subsequently received degrees from McGill University, was the first botanical explorer of note to have been born and educated in British North America. His earliest botanical specimens were obtained along the St. Lawrence River from Québec City to the Gaspé Peninsula, and along the Saguenay River up to Lac Saint-Jean, in 1857 and 1858, at which time he was a newly appointed employee of the Geological Survey, and an engineering student at McGill during the academic year. In 1860, on an expedition mapping the shores of Lakes Huron and Superior, he collected numerous botanical specimens, some of which represented rare species of the dune-swale complexes and alvars. On another such expedition in 1866, he and his brother John Bell (1845-1878) obtained many more specimens from the Niagara Escarpment and from the islands in the northern part of Lake Huron (Pringle 1989). (Robert Bell's later expeditions to other parts of Canada are discussed below.)

Another important development of the late 1850s and 1860s was the increasing popularity of botany as a hobby and the proliferation of local scholarly societies in Canada, following trends already established in Britain and the United States. A few such societies already existed, notably the Literary and Historical Society of Québec, founded in 1823, and the Natural History Society of Montréal, founded in 1827 (Chartrand et al. 1987: 79-86; Zeller 1987: *passim*, especially 193-197; Duchesne and Carle 1990). The precursors of the new societies were often "Mechanics' Institutes," which combined a social function with those of libraries and continuing education. Societies varied from city to city in their degree of specialization, but those in the major cities, including Halifax, Montréal, Ottawa, Toronto, and Hamilton, stimulated floristic studies, at least on a small scale, by publishing articles on the local flora in their journals (although the earlier articles in these journals usually lacked documentation and made no attempt at thoroughness). The Canadian general-scientific journals published by these societies prior to 1880, with the original titles and the dates of the first volumes, were: *Transactions of the Literary and Historical Society of Quebec*, 1829; *Canadian Journal of Industry, Sciences and Art* (Canadian Institute, Toronto), 1856; *Canadian Naturalist and Quarterly Journal of Science* (Natural History Society of Montreal), 1856; *Nova Scotian Institute of Natural Science Proceedings and Transactions*, 1863; and the somewhat more specialized *Ottawa Field-Naturalists' Club Transactions*, 1879. (Titles of early volumes changed frequently; see Lawrence et al., 1968 or union lists for further bibliographic details.) Later some of these societies included herbaria in their museums.

One of Canada's most famous writers, Catharine Parr Traill, née Strickland (1802-1899, on whom see Dore 1966, Eaton 1969, and other references cited by Stafleu and Cowan 1986; also Peterman 1990 and Catling et al. 1992), might have figured more prominently in the present study had not her herbarium been destroyed by fire in 1857. After this date her preparation of herbarium specimens—in sets as gifts

and for sale to other naturalists—seems to have been rather desultory and insufficient to document her publications. Her *Studies of Plant Life in Canada*, published in 1885 and representing some 50 years' observations in the "backwoods" near Rice Lake, Ontario, discussed numerous native species that had been identified, in her later years, with the assistance of James Fletcher (below).

George Lawson (1827-1895, on whom see MacGregor 1896; Mackay 1896; Boivin 1980, 1981; Connor 1986; Zeller 1987, 1990; and Smallman et al. 1991), called "the father of Canadian botany" (a title also bestowed upon John Macoun and J. Horace Faull), came from Edinburgh to Queen's University in Kingston, Canada West, in 1858. His background included botanical studies under J. H. Balfour in Edinburgh and a doctorate in botany — the first held by a resident of Canada — from Giessen, Germany. Soon after his arrival he founded the Botanical Society of Canada (on which see Connor 1986; Zeller 1987: 232-237 and references cited therein; Zeller 1990; and Smallman et al. 1991), with its members mostly in the Kingston area, but with some elsewhere in the province. It sought grants from the Colonial government for support of botanical exploration and for collaboration with W. J. Hooker on a manual of the Canadian flora, but these efforts came to naught. (Its attempts to be a United Provincial rather than a local society, and probably to obtain government support as well, were limited in part by perceptions of rivalry or unwarranted fragmentation of Canada's efforts in natural history — specifically from Hincks and the Canadian Institute in Toronto and from the Natural History Society in Montréal [Zeller 1987].) In 1860 the Botanical Society launched its *Annals*, containing articles on diverse aspects of the plant sciences, contributed not only by its own members but by some distinguished foreign botanists as well, including W. J. Hooker and Asa Gray. Members contributed specimens from various parts of the province for the Society's herbarium, as did Queen's students and several individuals presumably recruited by members outside the Kingston area. Lawson also had his own herbarium, representing his own extensive botanizing in Canada and exchanges with botanists elsewhere.

Dissension soon arose within the Queen's University faculty and between faculty members and the Presbyterian trustees (discussed at length by Smallman et al. 1991; see also Connor 1986 and Zeller 1987), and in 1863 Lawson moved to Dalhousie University in Halifax, which was just beginning its university functions despite its much earlier charter. Its promising beginnings notwithstanding, the Botanical Society of Canada soon disbanded, but Lawson remained active in botany, and published monographs on the ferns and "fern-allies," Ranunculaceae, Ericaceae, and *Melilotus*, *Viola*, *Myosotis* species of British North America, as well as notes on the Nova Scotia flora, economic plants, algae, and other botanical topics (see Bourinot 1895 and Adams et al. 1928-1951 for titles). Soon, however, his botanical studies were limited by his service as Secretary of Agriculture for Nova Scotia as well as by his commitments to chemistry at Dalhousie. As time permitted he worked on a descriptive flora of Canada, but, except for "Part I, Ranunculaceae" (Lawson 1870), this was never published. (The manuscript still exists in Ottawa.) He did publish two successive fern floras of Canada (Lawson 1864, 1889), and began publication of a list of the known flora of Nova Scotia, with localities, but was only able to complete the listing of the polypetalous dicots before his death (Lawson 1890).

In Nova Scotia as in Ontario, Lawson encouraged local botanizing by numerous amateurs. The Nova Scotian Institute of Natural Science began publication of its *Proceedings and Transactions* shortly after his arrival, with frequent notes on the flora. Among the more important collectors of plant specimens and contributors of botanical notes during the 1860s and 1870s were Edward Henry Ball (1843-1922), an Anglican clergyman who successively served twelve parishes throughout the province, author of a list of Nova Scotia ferns (Ball 1876-1879); Henry How (1828-1879), an alumnus of Glasgow, professor of chemistry and natural history at King's College in Windsor from 1855 until his death, better known for his achievements in mineralogy; and John Somers (ca. 1844-1898), a physician who helped found the Halifax Medical College, author of several notes on the vascular flora, mosses, and fungi. (On these naturalists see *Proceedings and Transactions of the Nova Scotian Institute of Science passim* and, on Ball, Anonymous 1922; on How, Vroom 1941; and on Somers, Anonymous 1898). Andrew Walker Herdman Lindsay (1852-1915) organized his and others' records into a checklist of the known provincial flora (Lindsay 1875, q.v. for names of other amateurs of the time). When he compiled this list, Lindsay was an undergraduate at Dalhousie; later he graduated in medicine from Edinburgh and became professor of anatomy at the Halifax Medical College (Anonymous 1915; Stewart 1915).

George Lawson
(portrait originally published in Proceedings and Transactions of the Royal Society of Canada, series II, 2(Proceedings): B3.

Québécois Botanists Become Active

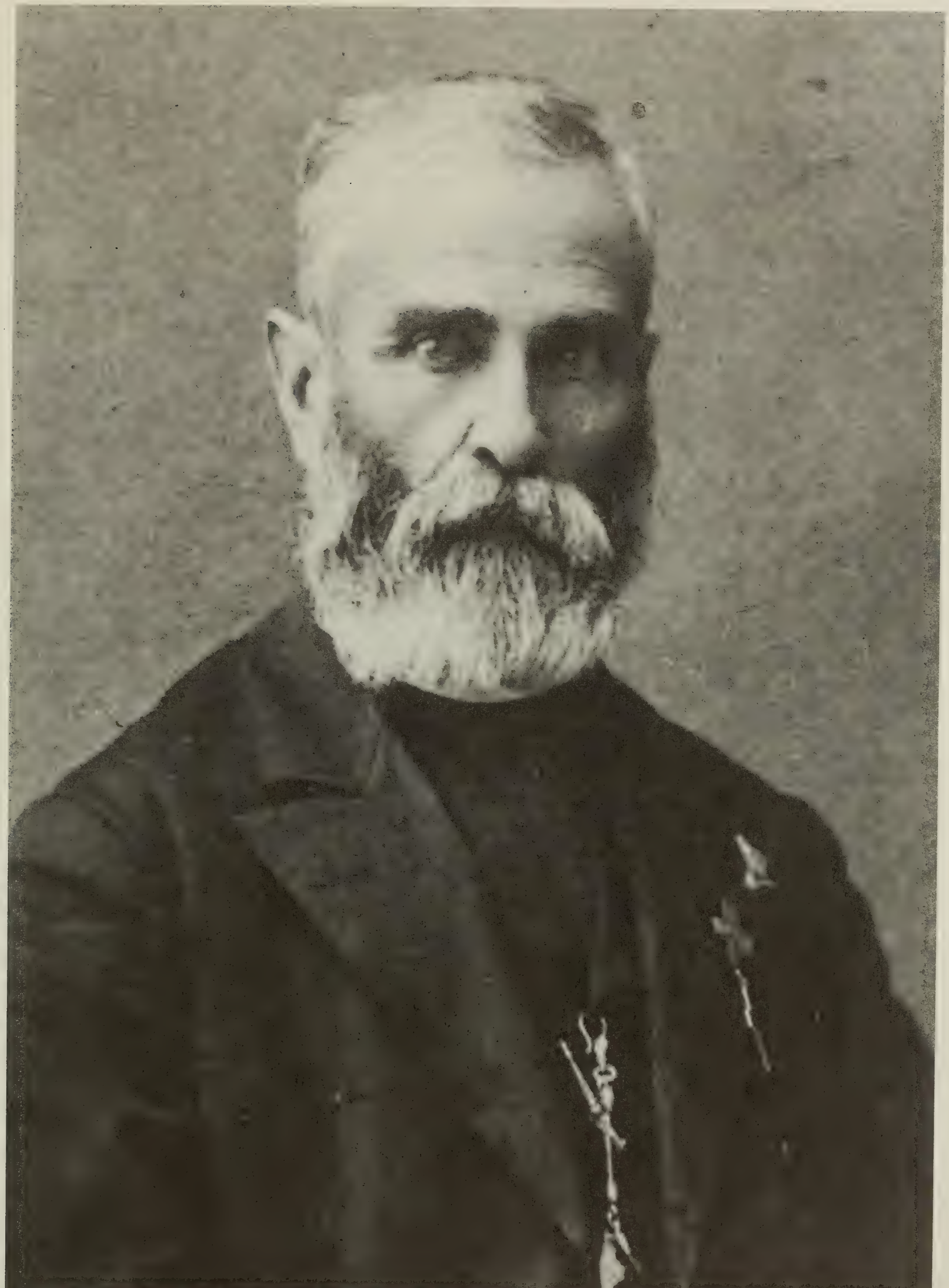
Meanwhile, in francophone Canada another botanical tradition was developing that would continue largely distinct from those of anglophone Canada for a century, at times becoming the most productive component of floristic studies in the country. In the mid-nineteenth century, French-language post-secondary education in Canada East was largely dedicated to preparation for the priesthood and the monastic orders. The first French-language university was Laval, originally a seminary, which attained university status in 1852; the present Université de Montréal opened as a branch of Laval in 1878. Even after schools and curricula diversified, faculties of the colleges and universities consisted mostly of monks and priests. This was a mixed blessing for botany. Academic opportunities were largely restricted to those who were sufficiently orthodox in their religious beliefs and willing to take the vows of their orders. On the other hand, the system supported a cadre of educated men with adequate time for intellectual pursuits, and provided the resources that were becoming increasingly important for botanical studies.

Abbé Léon Provancher (1820-1892, on whom see Huard 1894-1899; Béique 1968; Cinq-Mars 1968; Rousseau and Boivin 1968; and other publications cited by Stafleu and Cowan 1983; also Duchesne 1981 and Perron 1990), successively vicar or curé of several small-town churches in Canada East, was one Canadian botanist who saw his flora through to publication. *Flore Canadienne* was published in 1863. Its coverage of Canada East reflected extensive field work by Provancher and his contemporaries. Among Provancher's acknowledgments the most significant geographically was for lists of plants of Chicoutimi and La Malbaie sent by Judge Louis-David Roy (1807-1880); the most knowledgeable in botany of Provancher's correspondents was Augustin De Lisle (1802-1865) of Montréal (Lortie 1976). Coverage of Canada West was derived largely from Hooker's *Flora Boreali-Americana* of 23-34 years earlier. Varieties of *Fumaria* and *Picea* described in the *Flore Canadienne* (the former now generally reduced to synonymy, the latter occasionally recognized as a form) appear to have been the first new taxa to have been named by a resident of Canada. *Aster borealis* (Nees) Prov., still recognized, was the first species named by a Canadian, although it was based on *A. laxifolius* [var.] β *borealis* Nees. Several arbitrarily replaced scientific names and many validly published new combinations, mostly at varietal rank, were also included (Rousseau and Boivin, 1968). After retiring to Cap-Rouge near Québec City in 1872, Provancher concentrated primarily on entomology and published a number of historically important works on Canadian insects. Until his death, however, botanical notes continued to appear among his contributions to *Le Naturaliste canadien*, a journal that he had founded in 1869. (This journal was published continuously until 1993, when it was succeeded by *Écoscience*. *Le Naturaliste canadien* was revived, published by a La Société Provancher, in 1995, apparently destined for roles primarily in the popularization of science and promotion of conservation rather than resuming its former role as a research journal. Its history has been reviewed by Perron [1995].) One of Provancher's most significant botanical contributions from this period was a list of plants of the Magdalen islands (îles de la Madeleine), in an account of field work that also included lists of invertebrates and many other observations on the natural history of the Islands (Provancher 1890).

Another priest with similar interests — which unfortunately led to a sense of competition rather than cooperation with Provancher — was abbé Louis-Ovide Brunet (1826-1876, on whom see Robitaille 1930; Maheux 1960-1962; Rousseau 1972; Duchesne 1981; and Chartrand et al. 1987), who became professor of natural history at Laval in 1858. Brunet conducted field work in various parts of the United Province, north to Lac Saint-Jean and west to Niagara Falls and Chatham (details given by Maheux 1960-1962), and later on Anticosti and in the vicinity of the Strait of Belle Isle; studied herbaria (including Nuttall's and Michaux's type specimens) and botanical gardens in Europe; and corresponded and exchanged specimens with many botanists. Asa Gray strongly encouraged Brunet's plans to write a flora of Canada, to be "more complete and more reliable than Provancher's" (Chartrand et al. 1987, translation), but Brunet's failing health prevented him from completing this work. He was able to publish lists of the genera and the woody species of Québec and the specimens in the Laval herbarium (Brunet 1864, 1865, 1867), along with textbooks; the unfinished manuscript for his flora still exists at Laval.

A flora of Canada was also projected by abbé Jean Moyen (1828-1899), who taught natural sciences at the Collège de Montréal, but he returned to France before making much progress toward this goal (Provancher 1873; Chartrand et al. 1987; Duchesne 1990). He did publish a botanical textbook while in Canada (Moyen 1871), with guides to the identification of wild and cultivated plants. Moyen's own collections comprised about 500 specimens from the vicinity of Montréal (Boivin 1980).

A québecois layman especially active in natural history at this time was Dominique-Napoléon Saint-Cyr (1826-1899, on whom see Huard 1899 and Duchesne and Carle 1990), successively a teacher, politician, and founder and curator of the Musée de l'Instruction publique de Québec. In 1882 and 1885



Abbé Léon Provancher
(courtesy of les Archives Léon-Provancher, l'Université Laval).

he collected botanical specimens at remote localities on the Gulf of St. Lawrence, including Anticosti, the Mingan Islands, l'île du Gros-Mécatina, and several localities on the north shore. Unfortunately, the locality data on some of his specimens are now considered unreliable (R. Cayouette *in* Pryer and Phillippe 1989). Numerous herbarium specimens were also collected around the turn of the century by père Joseph-Célestin Carrier (1853-1904, on whom see Huard 1904 and Duchesne and Carle 1990), a teacher at the Collège de Saint-Laurent, Montréal. These were mostly from l'île de Montréal, for which he published a floristic list (Carrier 1901-1904). Other amateur botanists in Québec during this period have been noted by Chartrand et al. (1987) and by Duchesne and Carle (1990).

Post-Confederation Developments: The Macoun era

In 1867 Confederation joined Canada (in the 1841 sense) with Nova Scotia and New Brunswick in the new Dominion. Canada East and Canada West became, respectively, the provinces of Québec and Ontario. The federal government had increased autonomy and, significantly in the present context, a greater population base to support such institutions as a unified geological survey.

Much of present-day Canada remained outside the new nation. This included the vast watershed of Hudson Bay, called Rupert's Land, that had been granted to the Hudson's Bay Company over two centuries earlier. The Company's interest was in the fur trade, and it had no desire to see this territory populated by European settlers. By and large this attitude deterred floristic and other scientific studies, but some H.B.C. factors deserve credit for the botanical specimens they sent to England. These include James Anderson (1812-1867), Robert Campbell (1808-1894, not to be confused with Robert Campbell [1835-1921], a clergyman who botanized in Québec and Ontario in the 1890s), and William Mactavish (1815-1870, one of the founders of the ambitious but short-lived Institute of Rupert's Land in 1862), all of whom collected specimens along the Mackenzie River in the 1850s and 1860s. (For additional names see Porsild and Cody 1980; on the Institute of Rupert's Land and related topics, see Zeller 1987: *passim*, especially page 253.) Data, unfortunately, were imprecise at best, and in some cases the datum "Mackenzie River" appears to have become associated with specimens actually from localities farther south (Boivin 1972). Eugène Bourgeau had recognized the agricultural potential of the northern prairies, and Canada was eager to annex this territory. (One of the more contentious figures in the annexation movement was John Christian Schultz [1840-1896], who had collected botanical specimens from the Red River Settlement in present-day Manitoba in 1860.) Rupert's Land was surrendered by the Hudson's Bay Company in 1869. British Columbia, no longer isolated, became part of Canada in 1871, and Prince Edward Island joined in 1873.

With its new transcontinental purview, the Geological Survey of Canada launched the British North American Boundary Survey in 1873 — a two-year expedition from Lake Superior to the Lake of the Woods and west along the 49th parallel to the Rocky Mountains. The geologist and botanist was George Mercer Dawson (1849-1901, son of J. William Dawson; on G. M. Dawson see Hinde 1897). Much of the botanizing was actually done by the surgeon, Thomas Joseph Workman Burgess (1849-1925, on whom see Pringle 1989). Burgess later botanized extensively in Ontario and established a reputation as Canada's foremost pteridologist of his time. Dawson's distinguished career in geology subsequently took him to Vancouver Island, the Queen Charlotte Islands, the dry plateaus of interior British Columbia, the Skeena valley, and the Rockies during the next two decades. He also explored the Yukon Territory, contributing botanical specimens to the Survey herbarium from the remote Finlayson, Lewes, and Pelly river valleys (Hultén 1940) and from localities near the Alaska border, where the best-known mining town of the Klondike gold rush was named for him. Robert Bell (above) also continued in the service of the Geological Survey, and contributed botanical specimens obtained while mapping northern Ontario, mostly along the Albany, Attawapiskat, and Kenogami rivers, from 1870 through 1886 (Dutilly et al. 1954), and from the vicinity of Great Slave Lake in 1899. Another renowned geologist and explorer in the service of the Geological Survey during the late nineteenth century was Albert Peter Low (1861-1942, on whom see Alcock 1954 and Caron 1965, the latter including a map of Low's itineraries in northern Québec and Labrador). Low and his associates collected botanical specimens on several expeditions, including some in which J. M. Macoun participated (below). The most significant botanical specimens associated with Low himself were from the Ashuanipi and other rivers above Grand Falls (now the site of Churchill Falls Dam) in remote western Labrador, obtained in 1894. In 1896, Low and the naturalist William Spreadborough (1856-1931, on whom see Taverner 1933 and Waiser 1989) brought back botanical specimens from their explorations of northern Québec from Richmond Gulf (Lac Guillaume-Delisle) east and northeast to Fort Chimo on Ungava Bay.

It was during this period that the premier figure in the whole history of Canadian floristics appeared on the scene. John Macoun (1831-1920; /ou/ as in

ground, not as in *group*) in 1860 was a schoolteacher in Castleton, Ontario, studying botany largely on his own, but receiving valuable guidance through his correspondence with Hincks, Bell, and several leading botanists in Britain and the United States. Among the latter, Chester Dewey and Asa Gray were much impressed by his letters and his specimens. The establishment of the Botanical Society at Kingston, about 130 km down the lake, enabled Macoun to meet Lawson and to gain greater recognition from Canada's natural-history fraternity. When Albert College in Belleville added a university-level component in 1868, Macoun was offered a faculty position.

Macoun's early field work was in southern Ontario, from Northumberland County to Lennox and Addington County. In 1869 he made his first trip to Lake Superior, having been commissioned by George Barnston (1800-1883, author of notes on the distribution of some plants in Canada) and David A. P. Watt (below), both of Montréal, to collect specimens for their herbaria. During two months in the field, Macoun discovered disjunct populations of several species not hitherto known from the Great Lakes region, including *Cystopteris montana* (Lam.) Bernh. and *Cypripedium passerinum* Richardson. In 1871 he was a guest of Mr. and Mrs. William Roy at their home just outside Owen Sound, Ontario. Mrs. Roy, née Jessie Dalrymple Gregg (1813-1885, on whom see Pringle 1989), was an amateur plant collector who had discovered a number of rare ferns in the area, including the first record of *Dryopteris filix-mas* (L.) Schott for Canada. Macoun's trips with the Roys extended across the Bruce Peninsula to Red Bay, where Macoun first saw the dune-swale complexes in which he later found many rare species.

In 1872, following a chance meeting, Sandford Fleming, of Canadian Pacific Railway fame, invited Macoun to join an expedition exploring western Canada for a transcontinental railway route (Map 6). The expedition traveled from Lake Superior to Winnipeg, west of which Macoun first beheld the prairies, where he was "astounded by the number of species and their luxuriance." The party crossed the prairies via Forts Carlton and Edmonton, then went north to Lesser Slave Lake and the Peace River. It was at this time that the well-known incident occurred in which Macoun became convinced that his companion, Charles Horetzky, planned to maroon him in the unexplored mountains near Pine Pass with winter approaching. Macoun stuck to the Peace and Parsnip rivers, which he followed to Fort MacLeod (now MacLeod Lake, British Columbia). He returned to Belleville via the United States (see map in Waiser 1989: 22).

In the summer of 1874, Macoun and fellow Albert faculty member John Gibson (ca. 1852-1876) explored the Lake Huron shore from Grand Bend around the tip of the Bruce Peninsula to Owen Sound, and discovered a number of populations of rare species hitherto unreported from the Bruce Peninsula (Gibson and Macoun 1875a,b; Pringle 1989). Gibson, an Edinburgh-educated geologist, had become keenly aware of the relationships of plant distribution to soils and to geological history while he was studying the physiography of his native Huron County, Ontario. Gibson and Macoun worked on a manual of the flora of the St. Lawrence valley, of which only the section on the Caryophyllaceae (Gibson and Macoun 1875?) was published, and contemplated a flora of all of Canada. Many such benefits might have accrued to Canadian botany had Gibson not become terminally ill on an expedition to Lake Superior in 1876.

Macoun's report on his observations from the Canadian Pacific Railway survey convinced Albert R.C. Selwyn, head of the Geological Survey of Canada, of the value of studies of the vegetation as a basis for assessing the agricultural potential of the Canadian prairies and aspen parkland. In 1875, on leave from Albert University and seconded to the Geological Survey, Macoun was back in British Columbia, exploring the valleys of the Fraser and Thompson rivers. Along the latter, near Spence's Bridge, he encountered a flora that he later described as resembling that of Nevada and Utah; his discoveries included the first British Columbia records of *Crepis occidentalis* Nutt. var. *nevadensis* Kellogg (= ssp. *conjuncta* Babc. & Stebbins) and the disjunct populations of *Astragalus beckwithii* Torr. & A. Gray var. *weiserensis* M. E. Jones. Farther north, near Fort St. James, Macoun made "an enormous collection of interesting plants" from Stuart Lake Mountain (now Mount Pope). He also climbed Mount Selwyn, where he was impressed by the abundance of showy alpine species. On the trip east Macoun had further perilous adventures, but his specimens had been sent back from Fort St. John via New Westminster, and this return trip afforded no opportunities for botanizing (Map 6).

The following three years were spent in Ontario. Then in 1879 Macoun, who had resigned from the university to work full-time for the Geological Survey, traveled west from Winnipeg to Long Lake (now Last Mountain Lake, Saskatchewan) (Map 7). Impressed by the abundance of *Lilium philadelphicum* L., *Astragalus* and *Hedysarum* species, and other showy plants, he called the vicinity of this lake "the flower garden of the North West." (Ironically, Macoun's reports would hasten the replacement of much of this diverse and colourful flora by a monoculture.) He continued west to the "Elbow" of the South Saskatchewan River, thence to Battleford and Calgary and north to Edmonton, and returned to Winnipeg in the autumn.

In 1880 Macoun crossed present-day southern Saskatchewan and explored the Cypress Hills, where

MAP 6. John Macoun's Peace River expeditions, 1872 and 1875 (from Waiser 1989: 22, with the permission of W. A. Waiser and the University of Toronto Press).

MAP 7. John Macoun's western expeditions as explorer for the Canadian government, 1879-1881 (from Waiser 1989: 51, with the permission of W.A. Waiser and the University of Toronto Press).

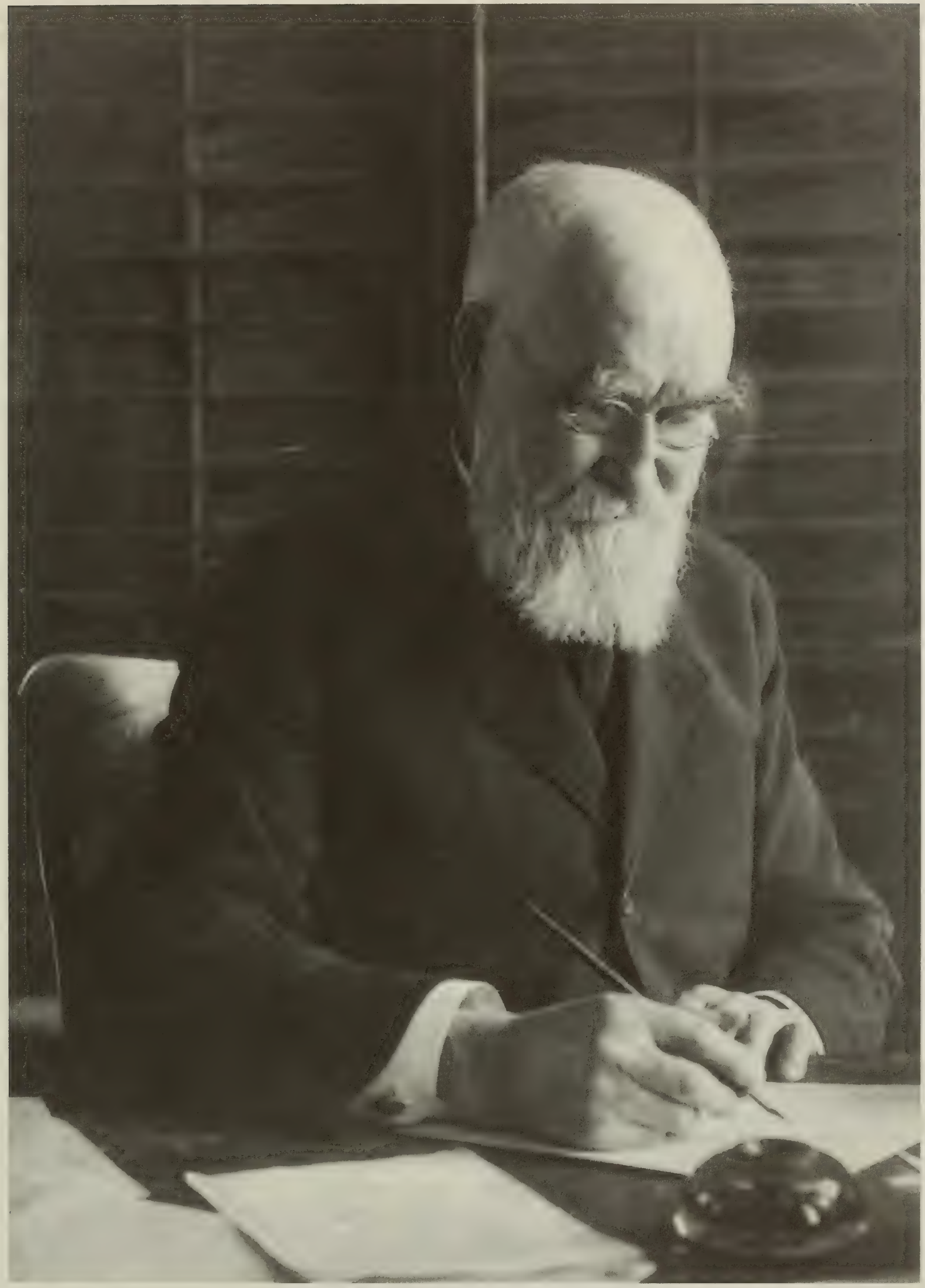
many Cordilleran species occur in outlying populations (Map 7). In 1881 he went north on Lakes Manitoba and Winnipegosis, up the Swan River and across the divide to the Assiniboine, which he followed south on his return to Winnipeg (Map 7). In 1882, he botanized along the Lake Erie shore, at localities including Amherstburg, St. Thomas, Point Pelee, and Pelee Island, and found a number of species at or near the northern limits of their ranges hitherto unknown from Canada. These included *Fraxinus quadrangulata* Michx., *Nyssa sylvatica* Marsh., and *Cercis canadensis* L., the last-named on Pelee Island, the only site at which it is known to have occurred as a native species in Canada. Burgess was among those who joined him at Point Pelee. Other notable discoveries in 1882 included prairie species such as *Silphium terebinthinaceum* Jacq. at or near their eastern limits; and the now-endangered *Plantago cordata* Lam. near Amherstburg. Later that year Macoun ascended the Shickshock Mountains (Monts Chic-Chocs) of Québec's Gaspé Peninsula, now noted for their disjunct populations of species adapted to serpentine soils. Among his discoveries on that occasion was a fern formerly considered to represent the first record of *Adiantum pedatum* L. var. *aleuticum* Rupr. in eastern North America, now called *A. aleuticum* (Rupr.) Paris.

Macoun was in then-poorly botanized Nova Scotia in 1883, mostly in the Annapolis Valley and on Cape Breton Island, and also on the island of Anticosti, Québec, in the Gulf of St. Lawrence. The next year he explored the vicinity of Lake Nipigon north of Lake Superior, and the Canadian Pacific Railway route east to Missinabi. In 1885 — after the Battle of Batoche and the return of peace to the Saskatchewan valley — Macoun crossed the prairies to present-day western Alberta, botanizing at localities including Kananaskis, Castle Mountain, and Banff, then crossing the divide to Rogers Pass. In 1887 he discovered "many rare species" on Vancouver Island. The following year he conducted "a thorough examination" of the flora of Prince Edward Island, which province had hitherto received almost no floristic study.

An abbreviated listing of Macoun's travels during the next thirteen years fails to do justice to his tremendous contribution to the knowledge of the Canadian flora, represented by tens of thousands of specimens in numerous herbaria. In 1890 he was back on the Fraser and Thompson rivers and in the vicinities of Okanagan and Kootenay lakes, British Columbia, after which he revisited Owen Sound, Ontario; in 1891 he botanized at Banff, having been asked to obtain plant and animal specimens for the new museum there, and later at Calgary and Indian Head (the last in present-day Saskatchewan); in 1892 he was on the Lake Erie shore and later on Vancouver Island and the adjacent mainland; in 1894 he made "large collections" in the Cypress Hills and around Medicine Hat; in 1895 he was in the same area and farther west, crossing present-day southern Alberta to Kootenay Pass in southeastern British Columbia, the source of "immense collections"; in 1896 he was in present-day Saskatchewan, with a month spent at Prince Albert; in 1897 he went to the Bow River valley and Crow's Nest Pass in the Rockies; in 1898 he spent the summer on Cape Breton Island, based at Alexander Graham Bell's summer home in Baddeck; in 1899 he botanized in the Halifax area of Nova Scotia with A. H. Mackay (below), and then went to isolated Sable Island, about 165 km off the Nova Scotia shore; in 1900 he studied the plants and birds of Ontario's Algonquin Park with William Spreadborough (above), with whom in other years he traveled in western Canada; and in 1901 he returned to Lakes Erie and Huron.

A major expedition to botanically unknown territory took place in 1902, when Macoun collected numerous specimens between Skagway, Alaska, and Whitehorse, Yukon Territory, and around Dawson. After staying close to home in the Ottawa region in 1903, Macoun visited many localities along the railway in present-day Alberta and British Columbia in 1904. In 1905 he explored the north shore of the St. Lawrence River between La Malbaie and Tadoussac; in 1906 he returned to the prairies, along the Grand Trunk Pacific route between Portage la Prairie and Edmonton; in 1907 he was again on the Gaspé Peninsula; in 1908 and 1909 he was on Vancouver Island, giving particular attention to marine algae; in 1910 he went to Nova Scotia; and in 1911 he botanized in the Ottawa area, sometimes with the ornithologist Percy Algernon Taverner (1875-1947, on whom see McAtee 1948 and Cranmer-Byng *in press*). After his retirement in 1912, Macoun lived on Vancouver Island, remaining active in botanical collecting and writing. (The present account of Macoun, including quotations, is derived largely from his autobiography [Macoun 1922]. Much information on Macoun has also been compiled by Rodgers [1944] and Waiser [1989], and many other publications on him have been cited by Stafleu and Cowan [1981].)

A new assessment of Macoun's career was recently written by Waiser (1989), a historian rather than a botanist, who stressed that Macoun's botanical contributions were largely restricted to collecting and listing. He correctly observed that Macoun was not truly part of "the mainstream of the new science of biology with its emphasis on pure, comprehensive research." This was almost inevitable in view of Macoun's educational background, his isolation from academic biologists, and the milieu in which he worked. As noted by Waiser, Macoun lived in an era when science in Canada was seen as having a very largely utilitarian role, at least if publicly supported,



John Macoun
(courtesy of the Canadian Museum of Nature).

and his "broad collecting activity, with its emphasis on practical results, was exactly the kind of science that Canadian politicians could understand and appreciate."

In a review of Waiser's book, Cayouette (1990) expressed concern over the criticism of Macoun that could be inferred from this emphasis, commenting that "in Macoun's time Canada was no doubt in need of specialists, but, inasmuch as the country was 50 years behind the United States in all realms of the natural sciences, it was first necessary to conduct exploration...that is what Macoun and his son [J. M. Macoun, below] did, in an exceptional manner, considering the means at their disposal" (translation). In the stricter context of the botanical exploration of Canada, Waiser and his reviewers agree that Macoun's position of pre-eminence remains unassailable. As Waiser expressed it, "What was most amazing about his collecting prowess was the range of territory he covered. His collections, moreover, were not only the first extensive ones made in particular areas, but in many instances were assembled before the natural environment was disturbed by man. It is not too exaggerated to say that John Macoun tried almost single-handedly to roll back the natural history frontiers of Canada."

Very few plant species new to science were among Macoun's specimens. Few species are native to the regions he explored that are not also native to the United States, and, in view of the activity in botany in the United States prior to the 1870s, Macoun's explorations were very late for such discoveries. Much is sometimes made of the number of "species" named for Macoun as their discoverer, but only one of the vascular plants, *Limnanthes macounii* Trel., a rare endemic of Vancouver Island and nearby islands, is still regularly accorded that status. (The name *Ranunculus macounii* Britton was published as a new name for a taxon already known to science, and in some other names the epithet honours J. M. Macoun.) *Aster anticostensis* Fernald, although not named for Macoun, is probably the only other currently accepted species having a name typified by Macoun's specimens (Labrecque and Brouillet 1990); this species, endemic to Anticosti, the Gaspé Peninsula, western New Brunswick, and formerly northeastern Maine, was discovered on Anticosti by Macoun in 1880. The name *Eleocharis* ×*macounii* Fern. (pro sp.), for plants now interpreted as hybrids between *E. intermedia* Schultes and *E. obtusa* (Willd.) Schultes, was also based on plants collected by Macoun, in this case at North Wakefield, Québec (Catling and Hay 1993). Nor did Macoun name any new taxa, except as the second author of many names for supposedly new bryophytes proposed by N.C. Kindberg. (This unfortunate aspect of Macoun's career — which, to his credit, he eventually recognized as such — has been discussed by Steere [1977].)

The best-known of Macoun's botanical publications is his *Catalogue of Canadian Plants* (Macoun 1883-1902). It was not the descriptive flora that he had hoped to write, but it listed all species of vascular plants, bryophytes, and lichens then known to occur in Canada, with localities and also with the names of the collectors and the authors of the many published reports that Macoun had studied. It served as a standard reference for nearly a century.

On many of his later field trips John Macoun was accompanied by one or both of his sons. William Tyrrell Macoun (1869-1933) became a horticulturist and director of the Central Experimental Farm in Ottawa (Byam 1934; Shutt 1933). James Melville Macoun (1862-1920, on whom see Malte 1920 and other publications cited by Stafleu and Cowan 1981; also Waiser 1989) was employed as his father's assistant at the Geological and Natural History Survey, as it was then called, from 1883 until his death. In addition to those on which he accompanied his father, J. M. Macoun undertook botanical expeditions of his own, often assisted by Spreadborough. Among his most significant early expeditions were those to the regions between Lake Winnipeg and Hudson Bay in 1883 and 1886, and along the Athabasca River in 1888. As a member of expeditions led by A. P. Low (above), J. M. Macoun collected specimens in the vicinity of Lake Mistassini and the Rupert River (rivière des Goélands) in 1885, and from the Moose River, the islands and east shore of James Bay, and Fort George River (La Grande Rivière) in 1887. (The only previous botanical exploration of the vicinity of Lake Mistassini was that by Michaux in 1792 and briefly by James Richardson [1809-1883, on whom see McCaul 1884] of the Geological Survey in 1870; the area was next visited for this purpose by Lepage and Dutilly [below] in 1943 [Blondeau 1987].) In 1890 he followed the Canadian Pacific Railway route from Vancouver to Eagle Pass near Revelstoke, British Columbia, then went to the Gold Range south of Revelstoke; in 1910 he was on the west shore of Hudson Bay, in 1912 in Strathcona Provincial Park on Vancouver Island, in 1913 in the vicinity of Ottawa, working on a flora of the region, and in 1914 in Jasper National Park and on the islands of the Strait of Georgia. In 1918 and 1919 he made "a most complete botanical survey of Jasper Park" (Malte 1920). He also discovered or identified many naturalized species in the flora of urban Canada, and prepared several sets of exsiccatae of Canadian bryophytes and lichens.

Canadian Floristics at the Turn of the Century: Scientific societies founded; Federal activity increases; Avocational botany peaks, then fades

Contemporary with the senior Macoun's employment by the Geological and Natural History Survey, botanical studies began to flourish in the Department of Agriculture, whose Plant Research Institute (later the Biosystematics Research Institute, then the Biosystematics Research Centre, and, as of 1992, the Biological Resources Division of the Centre for Land and Biological Resources Research) in Ottawa would assume a prominent role, at times the paramount role, in Canadian floristics and systematic botany during the twentieth century (Cody et al. 1986). In the 1880s the department's most active scholar in this field was James Fletcher (1852-1908, on whom see Bethune 1908; Harrington 1909 and other articles in *The Ottawa Naturalist* 22[10]; and other publications cited by Stafleu and Cowan 1976), a weed scientist and entomologist (although trained as an accountant), best known in the present context for his *Flora Ottawaensis* (Fletcher 1888-1893).

Carl Albert Purpus (1851-1941), a German horticultural collector who also prepared sets of exsiccatae and other herbarium specimens, and his brother, Joseph Anton Purpus (1860-1932), who was at that time a gardener at the botanical garden in St. Petersburg, Russia, visited Canada in 1887 (Diehl 1933; B. Ertter, personal communication in 1989). The senior Purpus's articles in *Der Ausland* indicate that he botanized in the upper valley of the Assiniboine River in western Manitoba, and later that year in British Columbia between Yale and Ashcroft and west to Lillooet Lake.

Following the discovery of gold near the present site of Dawson, Yukon Territory, in 1896, "numerous small collections" of plants from the Dawson area became available for study, to the extent that John Macoun wrote in 1899 that "our knowledge of the flora of the Klondike district is almost as complete as that of other parts of Canada." As with the early specimens from the Arctic, terse locality data published far to the southeast convey little of the hardships and dangers faced by the collectors of some of the Dawson specimens from 1898. Among the miners, government officials, and others who collected these specimens, two individuals are especially worthy of mention here. Joseph Burr Tyrrell (1858-1957, on whom see Inglis 1978) was a geologist and mining engineer whose diverse accomplishments included the confirmation of the presence of oil in Alberta. In 1898, while he was employed by the Geological Survey of Canada, Tyrrell obtained numerous specimens for the Survey's herbarium from the vicinity of Dawson (Macoun 1899). Robert Statham Williams (1859-1945, on whom see Barnhart 1945; Steere 1945; and other publications cited by Stafleu and Cowan 1988; on Yukon localities, see Hultén 1940) was a miner when he went to the Klondike in 1899, although he had been active as an amateur ornithologist and botanist for some time; later he held curatorial posts at the New York Botanical Garden. He was especially interested in mosses. His specimens, along with others from Alaska and the Yukon received at the New York Botanical Garden about the same time, were the subject of a series of papers by himself and several other botanists, in which many new taxa were described. Most of the new names in Britton and Rydberg's (1901) paper on flowering plants have since been relegated to synonymy, but several of the new taxa are still recognized, including two sedges named *Carex williamsii* and *C. bonanzensis* by Britton, the latter having been found at the mouth of the famous Bonanza Creek.

One of the largest botanical collections from the Yukon Territory during this time, although it was not seen by Macoun, was made by an expedition led by (Nils) Otto (Gunnar) Nordenskjöld (1869-1928), professor of geography at the University of Göteborg, Sweden, in 1898. Most of the botanical specimens were collected by (Oscar) Frithiof Andersson (1867-1911), who had just received his doctorate in paleontology from Uppsala (Munthe 1912; Hultén 1940). Yukon localities at which specimens were obtained included Bennett Lake near the southern Yukon border; Hootalinqua and Fort Selkirk; the valley and mouth of the Stewart River; and the vicinity of Dawson. Although this party traveled with hundreds of gold-seekers from Skagway to Dawson and arrived at Dawson only a week after Samuel Benfield Steele had taken command of the Mounted Police detachment there, it evidently resisted becoming involved in the gold rush, and moved on within a month. Other botanical collectors in the Yukon Territory during this period have been listed by Hultén (1940).

In 1913-1918 federal funds supported the Canadian Arctic Expedition, headed by Vilhjalmur Stefansson. Aspects of this expedition have been criticized, but not so the scientific work of the southern party, led by Rudolph Martin Anderson (1876-1961), a zoologist. Members of this party, notably Frits Johansen (1882-1957, on whom see Spärck 1957 and Porsild and Bousfield 1959), a Danish marine biologist, obtained numerous botanical specimens along the Arctic coast of the mainland from Alaska to Queen Maud Gulf, ca. 102°W (Macoun and Holm 1921). Indicative of the dearth of qualified Canadian botanists at the time, the preparation of the botanical report, after the death of J. M. Macoun, was assigned to (Herman) Theodor Holm (1854-1932), a Danish-born botanist then living in Clinton, Maryland, who had extensive experience in research on the vegetation of Greenland and the

alpine communities in the Rocky Mountains of Colorado (Woods 1933; Ewan and Ewan 1981). From 1922 to 1929, during which time he made his home in Ottawa, Johansen frequently returned to subarctic Canada, concentrating on crustaceans and other invertebrates but also contributing significantly to floristic knowledge, especially as a member of the Canadian Hudson Strait Expedition of 1927.

Many avocational plant collectors in Canada amassed large herbaria between 1865 and 1915. (Those known to have collected specimens in the Canadian basin of Lake Huron during the nineteenth century are listed in Pringle 1989, which gives an indication of their number and the extent of their contributions to botany.) It is feasible to mention here few others than those whose specimens were studied by John Macoun in the preparation of his *Catalogue* and those who authored significant works on the Canadian flora. One of the earliest was David Allan Poe Watt (1830-1917), a Montréal businessman active in the Natural History Society, especially during the 1860s and 1870s. His own specimens, emphasizing ferns, were obtained mostly in Québec, some in Ontario. Exchanges and collecting commissioned by him accounted for much of his large herbarium. Watt was another who planned to write a flora of Canada, but none of it was published. He did publish, *inter alia*, a catalogue of Canadian cryptogams (Watt 1865), updated by a later list of North American ferns (Watt 1867).

This increase in amateur plant collecting was accompanied by an increase in the number of societies devoted in whole or in part to natural history and in the activities of those few societies already established. (On the early history of such societies in Canada see Penhallow 1897; Chartrand et al. 1987; Zeller 1987; and Brunton 1994.) In Ottawa, the move of the headquarters of the Geological Survey to that city from Montréal in 1882 brought new vitality to the Ottawa Field-Naturalists' Club, providing leadership in botany from John Macoun and Henry Marc Ami (1858-1931, on whom see Reddoch 1976). Ami, by profession a paleontologist, was also a keen student of the Ontario and Québec flora.

From 1890 to 1904 the Entomological Society of Ontario, with its headquarters in London, had a second role as that city's *de facto* academy of science. Its several sections active during that period included a Botanical Section, whose members studied the flora around London and west to Lake Huron and discovered a number of rarities in the Carolinian vegetation. (Although C. Hart Merriam's "life-zone" terminology has otherwise almost entirely disappeared from use, the term "Carolinian" remains in general use in Canada for the deciduous-forest vegetation and flora of Ontario south of a line running through Grand Bend, London, and Toronto, although references are generally to the "Carolinian Zone" rather than to Merriam's "Carolinian Area" of the "Upper Austral Zone"; see Waldron and Colthurst 1994 and references cited therein.) These included *Isopyrum biternatum* (Raf.) Torr. & A. Gray (*Enemion biternatum* Raf.), *Stylophorum diphyllum* (Michx.) Nutt., and *Collinsia verna* Nutt., all of which were additions to the known flora of Canada (the last-named now believed to be extirpated). The "leading light" and first chairman of the Botanical Section was John Dearness (1852-1954), successively a schoolteacher, member of the Faculty of Medicine of the University of Western Ontario, and principal of the London Normal School, known best for his contributions to mycology but also for his knowledge of the vascular flora and for his large herbarium. Another member who contributed many floristic records was James Henry Bowman (1853-1936), a chemist. William Edwin Saunders (1861-1943), proprietor of a wholesale pharmaceutical firm, was also especially active in the Section and later on his own; called "the dean of Ontario field naturalists," he contributed primarily to ornithology but also botanized extensively in the province. (On the Botanical Section and its leading members, see Judd 1979 and publications cited therein; also publications cited in Pringle 1989.)

Other societies in Ontario cities, including the Canadian Institute in Toronto and the Hamilton Association for the Advancement of Literature, Science and Art, likewise included botanical groups that stimulated studies of the local flora around the turn of the century. Occasionally efforts were made to establish more specialized botanical societies, the primary purpose usually being to promote the exchange of herbarium specimens among private collectors, but these were generally short-lived and contributed little to floristic knowledge (Boivin 1981, 1986; Pringle 1989).

Additional amateurs in Ontario who deserve mention at this point are Braddish Billings, Jr. (1819-1871), an employee of the St. Lawrence and Ottawa Railway, who lived and botanized at the Prescott and Ottawa ends of the line, successively, during the 1860s and published a list of the plants of the Prescott area, considered by A. A. Reznicek (oral presentation at annual meeting, Botanical Society of America, Toronto, 1989) to have been the first modern-style local floristic list for any part of Canada; John Kerr McMorine (1842-1912), a clergyman who collected many specimens from eastern Ontario, mostly in the 1860s and 1870s; Andrew Thomas Drummond (1843-1921), who collected numerous plants around Kingston and elsewhere in Canada West, authored several papers on Canadian phytogeography (notably Drummond 1864, 1868, 1869, 1887-1888), and contributed significantly to the knowledge of Canada's lichen flora through specimens sent to Edward Tuckerman of Philadelphia;

Thomas Lomas Millman (1850-1921), assistant surgeon on the British North American Boundary Survey (above) and subsequently staff physician for the Independent Order of Foresters, whose large herbarium included many specimens cited by Macoun, mostly from Ontario; James White (1848-1931), a schoolteacher in Snelgrove (called Edmonton during much of White's time, now part of Brampton), who botanized extensively in southern Ontario, exchanged specimens widely, and published on the flora of Peel County; James Alexander Morton (1848-1932), a lawyer in Wingham, who made a number of interesting discoveries in Huron County and also exchanged specimens with many leading botanists; William Scott (1845-1920), a teacher in Ottawa and later headmaster of the Toronto Normal School, whose herbarium represented noteworthy discoveries made throughout much of southern Ontario; and William Herriot (1870-1930), a clerk in Galt (now part of Cambridge), who began his large herbarium in the 1890s, botanized on the prairies with John Macoun in 1906, and published a series of papers on the flora and avifauna of the Galt area in the *Ontario Natural Science Bulletin*, the journal of the rather short-lived Wellington Field Naturalists' Club, based in nearby Guelph. Equally worthy of mention for his extensive botanizing, especially in Huron County, but not an amateur, was Absalom Cosens (1869-1938), a high-school botany teacher in Toronto and senior author of a botany textbook that was widely used in Ontario schools. (On McMorine see E. G. Ross 1969, 1984; on Drummond see Zeller 1987: 248-251; on Millman see Anonymous 1921; on the others see Pringle 1989 and publications cited therein.) Similar trends in the United States brought many American amateurs to localities along the border and occasionally farther into Canada, including Charles Keene Dodge (1844-1918), who botanized extensively along southern Lake Huron and western Lake Erie and on the St. Clair delta (Voss 1978).

In 1891 George Lawson (above) founded the Botanical Club of Canada, primarily to promote and coordinate floristic studies (Lawson 1892; Zeller 1990). After Lawson's death in 1895 this organization was led by Alexander Howard Mackay (1848-1929, on whom see McMurrich 1930), and concentrated on phenology and on botany in the public schools rather than on herbaria and floristics (Boivin 1980, 1981). Nevertheless, Mackay himself, a high-school principal first in Pictou, Nova Scotia, then in Halifax, and subsequently head of the Nova Scotia Department of Education, became the foremost botanical explorer in Nova Scotia in the late nineteenth and early twentieth centuries, and published many notes on the vascular flora as well as on phenology and on algae (including Mackay 1903, 1906, as well as popular notes; for a complete list see Adams et al. 1928-1951). Another naturalist active in Nova Scotia during the late nineteenth century was Charles Budd Robinson, Jr. (1871-1913), who botanized in the Pictou region and compiled floristic records contributed from public schools around the province; these were published by the Nova Scotian Institute of Science in its *Proceedings and Transactions*. Robinson, at that time a high-school teacher in Pictou, was later employed as a systematic and economic botanist by the New York Botanical Garden and the Philippine Bureau of Science (Britton 1914; Merrill 1914; Desmond 1994; Stafleu and Cowan 1983; and references cited therein).

Arthur Charles Waghorne (1851-1900, on whom see Brassard 1980), an Anglican clergyman who served several parishes in Newfoundland, was an assiduous student of Newfoundland's flora and made several trips to Labrador. He exchanged specimens widely and enlisted the aid of several prominent botanists in the United States, as well as James Fowler (below) and John Macoun, in identifying his plants. He began publication of a list of the known (and reported) plants of Newfoundland, Labrador, and the French islands, with localities, intending to cover both vascular and non-vascular species, but only the portions on the polypetalous and gamopetalous dicots had been completed at the time of his death (Waghorne 1893-1898). These, too, were published by the Nova Scotian Institute, of which he was an esteemed corresponding member.

In New Brunswick, one of the leading figures in botany during this period was James Fowler (1829-1923), who at that time was a Presbyterian clergyman. In 1879-1880 and 1885, respectively, Fowler published two lists of the known vascular flora of the province (Fowler 1885; see Bourinot 1895 and Adams 1928 for earlier titles). In 1880 he became a faculty member at Queen's University in Kingston, Ontario, teaching natural science, which initially included botany, zoology, and geology. There he established the university's herbarium, in which he deposited specimens from his own botanizing "from Vancouver Island to Canso [Nova Scotia]," and to which many students and others also contributed. During the 1890s and 1900s Fowler often spent summers at federal biological stations in the Maritimes, where "he collected...thousands of plants year after year" and authored several papers on the flora (Beschel 1966; Young 1986; Smallman et al. 1991; Crowder et al. 1993).

Loring Woart Bailey (1839-1925), Robb's successor as professor of chemistry (this later dropped) and natural science at the University of New Brunswick from 1861 to 1907, distinguished himself primarily in geology but also contributed a substantial quantity of vascular-plant specimens to that university's herbarium. After his retirement he returned to the study of diatoms — an early interest — and pub-

lished several papers on these algae in Atlantic Canada (Ganong 1925; on herbarium specimens see Penhallow 1897; Boivin 1980; and Young 1986). Other members of the Natural History Society of New Brunswick, led by George Upham Hay (1844-1913, on whom see Matthews 1914), a high-school teacher in Saint John, also studied the New Brunswick flora during this time. (See Young [1986] for the names of other members of the Society who botanized in New Brunswick at this time.) From 1884 through 1911, this group reported their floristic discoveries in the Society's *Bulletin*.

Concurrently, on the opposite side of the country, Joseph Kaye Henry (1866-1930, on whom see Stafleu and Cowan 1979 and Boivin 1980), a schoolteacher in Vancouver and later a professor of English at the University of British Columbia, was studying the flora of southern British Columbia, on which he published a descriptive flora in 1915. Although Henry acknowledged extensive use of Macoun's *Catalogue* and floras of adjacent states, this flora represented the results of much field and herbarium work by himself and incorporated his own taxonomic judgments. Several new taxa were described. In 1911, British Columbia appointed a Provincial Botanist, John Davidson (1878-1970), a former museum curator in Scotland, who explored then-remote and floristically unknown regions of the province, including the coastal mountains and the dry interior. Davidson was most active in field work while he held this position, although he continued to make contributions to botany after being appointmented instructor in botany at the newly founded University of British Columbia in 1917 (Brink 1970). In Victoria, James Robert Anderson (1841-1930), of the British Columbia Department of Agriculture, collected plants, mostly from Vancouver Island, for the departmental herbarium, which later constituted a major addition to that of the Provincial Museum. In the Rocky Mountains of Alberta, numerous plants were collected by Norman Bethune Sanson (1862-1949). Sanson, who had been a bookkeeper and insurance agent, left the amateur ranks in 1895 to become curator of the new museum at Banff (Ewan and Ewan 1981; Hallworth 1985).

The work of Hay, Henry, Herriot, and their contemporaries, whose last papers were published in 1912-1915, marked the end of an era. "Natural theology" and the importance attached to botany in the pursuit of self-improvement and "gentility," which presumably had motivated amateurs in Canada as in the United States, had given way to other philosophies (see Keeney 1992: 49-50). Even the upper classes often occupied smaller homes, as higher taxes and wages reduced domestic staffs, and there was less room for natural-history "cabinets." By the early years of the twentieth century, in Canada as Keeney (1992: 50) noted in the United States, "new attractions like baseball and bicycling made the exercise of collecting seem tame and dull by comparison." A new generation, with automobiles and radios added to the new attractions, and soon to become more "worldly-wise" as a result of World War I, developed its own recreational and avocational interests. To the foregoing, Shinners (1962) added "extreme urbanization," which was characteristic of southern Canada as well as the United States, as a factor inhibiting the serious pursuit of botany by amateurs in the twentieth century.

For those amateurs who derived their satisfaction from a sense of having contributed to the advancement of science, this satisfaction became increasingly difficult to attain without more formal training, access to scientific literature and apparatus, and/or extensive travel. Lists of plants (generally excluding the grasses, sedges, pondweeds, willows, and other "difficult" groups) observed in the more populous parts of Canada, already having been published for many localities, no longer constituted significant contributions to knowledge. A bibliography of the natural history of the vicinity of Hamilton (Judd 1960), for example, shows that the first such list of plants was published in 1854; another appeared in 1861, with a supplement in 1870; and yet another in 1897, with supplements at intervals through 1905. After that time, obviously, it would be difficult to contribute much further without the knowledge, equipment, and references that would permit one to tackle the "difficult" or taxonomically controversial groups. Until about 1905 amateurs' observations of local plants had been published in the same journals as the most scholarly papers by the scientific luminaries of the day, but thereafter, with the greatly increased professionalization of the sciences, refereed journals imposed standards that excluded casual observations, especially those that scarcely more than repeated the observations of an earlier generation.

The old "literary and scientific" societies faded away during the period from 1905 to 1925 or survived only in altered roles. The more specialized natural-history societies that survived and remained dominated by amateurs no longer emphasized collections, and often concentrated largely on ornithology, as the pages of *The Canadian Field-Naturalist* show. Concurrent with this decline in amateur botany were the death of Fletcher and the retirement of both Fowler and John Macoun for reasons of health. James M. Macoun was active for a few more years in Ottawa and some hobbyists continued to collect plants, but unquestionably floristics entered another quiescent period in Canada.

In 1911, shortly before the retirement of John Macoun, the museum of the Geological Survey became the Victoria Memorial Museum (later, in 1927, the National Museum of Canada) and moved into a new building of its own in Ottawa. (On the

early history of the Museum, with emphasis on John Macoun's role, see Waiser 1989; on the history of the Museum within the Geological Survey of Canada, see Zaslow 1975). Sciences other than geology thereby more clearly had their own mandates, although the Museum, including the National Herbarium, remained under the jurisdiction of the Geological Survey, within the Department of Mines (name varied), until 1950 (below). Nevertheless, whereas amateur activity had declined, opportunities for professionals in botany and other branches of the natural sciences did not increase rapidly in Canada, and the progress of botany and the National Herbarium was very slow for the next quarter-century.

American Botanists Assume a Major Role

As in the period from 1835 to 1860, while field botany languished in Canada it was particularly vigorous south of the border. A marked increase in studies of the Canadian flora by United States botanists became evident before the turn of the century. In 1894 Harvard professor Benjamin Lincoln Robinson (1864-1935, on whom see Fernald 1937) and recent alumnus Hermann von Schrenk (1873-1953) made interesting botanical discoveries on Newfoundland's Avalon Peninsula (Robinson and von Schrenck 1897). Further additions to the known flora of Newfoundland were made in 1908 by Edwin Hubert Eames (1865-1948) and Charles Cartlidge Godfrey (1855-1927), physicians from Bridgeport, Connecticut (the latter also a noted amateur astronomer), who explored the island's southwest coast (Eames 1909).

Eight years after Robinson's visit to Newfoundland, his associate in the preparation of the seventh edition of *Gray's Manual*, Merritt Lyndon Fernald (1873-1950, on whom see Griscom 1951; Pease 1951; Rollins 1951; and Merrill 1954), went on the first of his many expeditions to present-day Canada. Fernald, a native of Maine, was keenly interested in the flora of Atlantic Canada. Not only did he become the United States' best-known plant taxonomist of his time; he ranks with Macoun and Marie-Victorin (below) in his contributions to the knowledge of the eastern Canadian flora. In 1902 and 1904, having become aware of rarities on the Gaspé Peninsula from Macoun's widely exchanged specimens, he visited the south shore of the St. Lawrence River around Rivière-du-Loup and east to the Gaspé, and the Saguenay valley above Tadoussac, north of the St. Lawrence. He returned to the Gaspé in 1905, 1906, 1907, 1922, 1923, and 1931, on some of these visits ascending Mt. Albert and Tabletop Mountain in the Shickshocks to study the disjunct populations of taxa occurring on serpentine soils. (See appendix to Fernald 1942 for a list of Gaspé expeditions by himself and other New England — mostly Harvard — botanists.)

In 1909 Fernald was in New Brunswick, botanizing with a party that included John Macoun. In 1912 he explored the isolated Magdalen Islands in the Gulf of St. Lawrence and also visited Prince Edward Island. In 1914 he botanized on Cape Breton Island, the northern half of which he described as "geologically, physiographically, and floristically very different from Nova Scotia proper." In 1920 and 1921 he visited mainland Nova Scotia, spending most of his time in the southwestern part. (On these expeditions see Fernald and Wiegand 1910; Fernald 1921-1922; and other publications by Fernald listed by Rouleau 1953 and Catling et al. 1986.)

Fernald was especially intrigued by the flora of Newfoundland, and in 1910 he began his expeditions to that island, exploring many difficult-to-reach interior locations. That first year he gave particular attention to the calcareous habitats of the Long Range and the areas of serpentine rocks along of the west coast, where many rare and disjunct species occur, some differentiated at the varietal or even specific level from their mainland relatives. The following year he concentrated on eastern Newfoundland, starting at Grand Falls and exploring many of the coves and islands east and south to the Avalon Peninsula. He briefly visited southwestern Newfoundland in 1914; then in 1924 he and his party botanized exuberantly in the vicinities of Port aux Basques in the southwest, Flower Cove near the northern tip, and Trepassey on the Avalon Peninsula. In 1925 he eagerly returned with another party to the Strait of Belle Isle, from Flower Cove to Quirpon. In 1926 and 1929 he botanized around the Bay of Islands, in 1929 continuing once again to the Strait of Belle Isle. In 1910 and 1925 Fernald's parties also visited localities on the north side of the Strait, on both sides of the Québec-Labrador border. Fernald (1911) considered Blanc-Sablon "an ideal place to study the vegetation of a highly calcareous region side by side with the plants of a siliceous and gneissoid area." (On Fernald's Newfoundland expeditions see Fernald 1911, 1926, 1933, and other publications by Fernald listed by Rouleau 1953; Laird 1980; and Catling et al. 1986.) After 1931 Fernald was advised by his physician to avoid the harsh climate of Atlantic Canada, and so he began his tremendously productive studies in southeastern Virginia. In 1934, however, en route to Michigan, he did some botanizing along the north shore of Lake Huron in Ontario (Fernald 1935).

Fernald made a vast number of phytogeographically and taxonomically important discoveries in the flora of the Gaspé Peninsula and the Atlantic Provinces. He authored several papers on the phyto-

geography of this region (notably Fernald 1911, 1918a,b, 1924; see Laird 1980 and Catling et al. 1986 for additional titles), concentrating especially on narrowly endemic taxa and on disjunct populations of species otherwise known only from the Rocky Mountains and/or the Arctic. These studies culminated in one of his best-known papers and certainly his most controversial, in which he postulated the persistence of plants in nunataks, or small areas that remained ice-free throughout the Wisconsinan glaciation, as an explanation of the disjunct populations in this region (Fernald 1925). From the Gaspé Peninsula and adjacent parts of Québec Fernald and his associates obtained nearly 200 type and paratype specimens (Scoggan 1950). Although many taxa with names thus typified, especially at infraspecific ranks, are still recognized, many other such names have been reduced to synonymy (Drury 1969). Better knowledge of the boreal and arctic floras has revealed that supposedly distinct, narrowly endemic taxa actually fall within the ranges of variation of widespread species. Some of the genera in which supposed new species with restricted ranges were described, such as *Antennaria*, are now known to include many local agamospermic populations sometimes designated "microspecies." One taxon still generally recognized is the orchid now called *Platanthera albida* (L.) Lindl. var. *straminea* (Fernald) Luer, known in North America (other than Greenland) from the populations found by Fernald in northern Newfoundland in 1925 (and later by others) and also from eastern Hudson Bay; Fernald was the first to recognize the distinctness of these plants, along with those of Greenland, Iceland, and the Færøe Islands, from those of the European continent. Specimens of *Cerastium terrae-novae* Fernald and Wiegand, a species restricted to serpentine soils in western Newfoundland, had previously been collected by Waghorne, but it was from his own discoveries of this species that Fernald recognized its distinctness.

Fernald's companions on his Canadian expeditions included many Harvard students, alumni, and faculty colleagues who were then or soon became distinguished amateur or professional botanists, notably Arthur Stanley Pease (1881-1964), the classics scholar who advised Fernald on Latin in the preparation of the eighth edition of *Gray's Manual*, and Bayard Henry Long (1885-1969), Charles Alfred Weatherby (1875-1949), Karl McKay Wiegand (1873-1942), and John Milton Fogg (1898-1982). James Franklin Collins (1863-1940) was an exception, being from Brown University. Biographies of all of these individuals have been published in *Rhodora*. Fernald was well acquainted with the work of frère Marie-Victorin (below), with whom he shared a special interest in the phytogeography of the Gulf of St. Lawrence region. It is most appropriate that Fernald's honorary doctorates were bestowed by Acadia University and l'Université de Montréal.

Harold St. John (1892-1991), one of Fernald's students, received support from the Geological Survey of Canada for botanical studies of several regions in eastern Canada, although the intervention of World War I prevented a permanent position with the Survey from materializing. In 1912, as a Harvard undergraduate, he accompanied Fernald and others to the Magdalen Islands; in 1913 he botanized in Nova Scotia, including Sable Island; in 1914 he continued his studies of the flora of the Magdalen Islands and also visited Newfoundland; and in 1915 he was on the north shore of the Gulf of St. Lawrence. His (1922) paper on the flora of the last-named region summarizes the history of its previous botanical exploration.

In 1909 an expedition led by Albert Spear Hitchcock (1865-1935), chief agrostologist of the U.S. Department of Agriculture, now noted for his *Manual of the Grasses of the United States*, collected specimens, mostly of grasses, at localities between Whitehorse and Dawson and also in British Columbia and Alberta. Hitchcock again botanized in Alberta in 1914 (Chase 1936; Hultén 1940; Ewan and Ewan 1981), and visited Newfoundland and Labrador in 1928. Alice Eastwood (1859-1953, on whom see Howell 1954), a native of Toronto associated for many years with the California Academy of Sciences, went to the Dawson area in 1914 on behalf of the Arnold Arboretum of Harvard University. Her numerous specimens were mostly of woody plants, with special attention given to *Salix* (Hultén 1940; Ewan and Ewan 1981).

Significant contributions to the knowledge of the flora of northwestern Canada were made by Hugh Miller Raup (b. 1901) of the Arnold Arboretum, sometimes with financial support from the National Museum of Canada. In the summers of 1926, 1927, and 1928 Raup and several associates studied the flora of the vicinities of Lake Athabasca and Great Slave Lake, and in 1929 that of Wood Buffalo National Park on the Alberta-Northwest Territories border. From both of these field studies Raup prepared annotated plant lists with phytogeographic discussions (Raup 1930, 1935), as well as several taxonomic and ecological papers. In 1939 he and James Herbert Soper (b. 1916) botanized at Fort Simpson on the Mackenzie River, and at remote Britnell Lake in the Mackenzie Mountains, near the head of the South Nahanni River, which they reached by plane. (Soper was then a graduate student at Harvard; subsequently he was, successively, a faculty member in botany at the University of Toronto and head of the Department of Botany at the National Museum of Canada. His later career included the authorship of floristic papers and plant-identification guidebooks for many areas of Canada.) Britnell Lake figured

Merritt Lyndon Fernald collecting *Draba aurea* Vahl s. lat. on Cap Enragé, Co. Rimouski, Québec, 1905 (photograph by J. Franklin Collins; courtesy of the Botany Libraries of Harvard University).

prominently in Raup's flora of the southwestern part of the District of Mackenzie, Northwest Territories, published in 1947. Between 1943 and 1948, Raup studied the flora along the Alaska Highway (Raup 1934, 1944; Porsild and Cody 1980; Stafleu and Cowan 1981).

Another American botanist who investigated the Canadian flora during the 1920s and early 1930s was Norman Carter Fassett (1900-1954, on whom see Peattie 1954), one of Fernald's students and later a faculty member at the University of Wisconsin, best known for *A Manual of Aquatic Plants*. Fassett's doctoral dissertation on estuarine plants included the results of field work along the coasts of the Maritime Provinces and eastern Québec in 1921 (adapted for publication as Fassett 1928). In 1931 and 1932 he botanized in Ontario between Sault Ste. Marie and Ottawa, including the Manitoulin Archipelago (Fassett 1933), a region much of which had received hardly any floristic study since the Bells' visits seven decades earlier.

Western Canada received less attention from United States botanists during the first three decades of the twentieth century. Mention should, however, be made of Edith May Farr (1864-1956) of Philadelphia, who published on the plants of southern British Columbia and Alberta from 1904 to 1906, including a list of the plants of the Selkirk Range and the southern Canadian Rockies based on her collections (Farr 1907). *Arnica louiseana* Farr, a distinctive species with nodding flower-heads, named for Lake Louise, Alberta, was described in one of these papers (Farr 1906) and remains generally accepted as a species. Also, Stewardson Brown (1867-1921, on whom see Stone 1924), of the Philadelphia Academy of Natural Sciences, botanized in the Canadian Rockies in 1906 and 1908 and wrote a field guide to the wildflowers (Brown 1907).

The Marie-Victorin Era: Resurgence of floristic and taxonomic studies, especially in Québec

During the latter years of the Macouns' tenure at the National Museum, when John Macoun was Chief Naturalist and J. M. Macoun was his assistant, the position of Dominion Botanist had officially been vacant. As the senior Macoun's retirement drew near, the Macouns sought for this position "a recognized botanical authority...who could name and describe plants new to science," thereby to free the Museum from dependence on "outside" experts. Fernald had been approached in 1906. Following the move to new quarters in 1910, J. M. Macoun actively recruited Edward Lee Greene, then of the Smithsonian Institution, for this position — rather a surprising choice, since Greene was 68 years old at the time of this recruitment and had a well-established reputation for eccentricity and irascibility, although he was seeking more congenial and more remunerative arrangements elsewhere. However, the director of the Geological Survey, R. W. Brock, felt that other branches of natural history at the Museum more urgently needed increased professional staff, and the position of Dominion Botanist remained vacant (Waiser 1989: 184).

Botany in Canada's Department of Agriculture during the 1920s and early 1930s concentrated largely on the applied branches, especially plant pathology, and the botanical complement at the National Museum had decreased since the days when both Macouns were there. Floristic and systematic botany, however, were not entirely absent from the federal scene in Ottawa. Virtually the only systematic botanist in Ottawa during this period was Malte Oskar Malte (1880-1934, on whom see Watson and Faull[?] 1934 and Fernald 1934). Malte's first positions in Canada (he was born and educated in Sweden) were in the Department of Agriculture, in which he became Dominion Agrostologist. Much of his activity at that time was in such areas as the evaluation of forage grasses, but from his arrival in 1911 he collected specimens of the native flora, especially in the Prairie Provinces. His move to the National Museum in 1920, first as curator of the herbarium and the following year as Chief Botanist, provided greater opportunities to work in his preferred field, and he spent much of his time botanizing across Canada. He was especially interested in the boreal and arctic flora, and he accompanied several government expeditions to Hudson Bay and the Arctic Archipelago. In collaboration with Carl Emil Hansen Ostenfeld (1873-1931) of Copenhagen and with further input from Morten Pedersen Porsild (1872-1956) of the research station on Disko Island, Greenland (see Pringle, 1995: page 366), he worked on a flora of arctic Canada, and at the time of Ostenfeld's and his own death had many taxonomic notes on arctic and subarctic Canadian plants in preparation. A portion of these were published posthumously in *Rhodora* through the efforts of Fernald. These included a monograph on *Antennaria* in Arctic North America and descriptions of the new species *Potentilla hyparctica* Malte and *Castilleja elegans* Malte, based on Malte's own discoveries on Ellesmere Island and at Coronation Gulf, respectively (Malte 1934a,b). Malte also contributed to the knowledge of the flora of New Brunswick, where he botanized during the summers of 1926, 1927, and 1929, and had made considerable progress toward a flora of the Maritime Provinces (not published) at the time of his death (J. Cayouette, personal communication in 1989).

Meanwhile, in the Department of Agriculture, Herbert Groh (1883-1971, on whom see Taschereau 1972) had begun his long career in weed studies, which contributed greatly to the knowledge of the distribution and spread of weedy and other naturalized species in Canada. Groh also contributed significantly to general floristic studies in Ontario and Québec, especially in the vicinity of Ottawa. Nationwide weed surveys by Agriculture Canada staff continued to make major contributions to Canadian floristics after Groh's retirement, with Clarence Frankton (b. 1906) and (Ivan) John Bassett (b. 1921) having collected especially large numbers of specimens from diverse regions in more recent years (Cody et al., 1986, q.v. for names of other participants).

Another factor in the history of Canadian floristics became much more important during this period. Although there were very few systematic botanists employed in the country, activity was gradually increasing in other branches of science, especially in federally supported exploration of boreal and subarctic regions. In the tradition of Bell, Dawson, and Tyrrell, geologists, anthropologists, zoologists, ecologists, and other scientists collected plant specimens from many parts of northern Canada—some because they needed plants identified for their ecological studies, others because they were aware that no components of the biota were well known in the regions they were exploring. Individually such collections usually contributed very modestly to floristic knowledge, but collectively they became a major source of new data.

Whereas in the present paper (above) 1916 has been presented as the beginning of a period of relative inactivity by Canadian botanists, Boivin (1986) saw that year as a turning point in Canadian botanical history, after which papers on floristics and plant taxonomy by Canadian botanists became much more numerous. Boivin's interpretation was inspired largely by a paper describing many new species of fungi, published that year by John Dearness (above). A comparable increase in taxonomic studies of true plants by Canadian botanists

Frère Marie-Victorin on Île de la Vache (Minganie), 3 August 1928 holding the Mingan Islands Thistle, *Cirsium minganense*, an endemic to the Mingan Islands which he had described in 1925. Photograph courtesy of Photograph archives, Montréal Botanical Garden.

was a few years longer in coming. It was in francophone Québec that phytogeography and vascular-plant taxonomy first burgeoned in twentieth-century Canada. Foremost in this renaissance was Canada's best-known botanist after the senior Macoun, frère Marie-Victorin (né [Joseph-Louis-] Conrad Kirouac, 1885-1944, on whom see Anonymous and Gauvreau 1938; Kucyniak 1946; Brouillet 1985; and other papers in *Bulletin de la Société d'animation du Jardin et de l'Institut botaniques* (Montréal) 9(3); Chartrand et al. 1987; McCready 1989; Charbonneau 1994-1995; and many other publications cited by Stafleu and Cowan, 1981 and Arsenault 1985; on his herbarium see Boivin 1980). After seventeen years as a secondary-school teacher, during which time he had studied botany with the help of his friend frère Rolland-Germain (below) and through extensive correspondence with Fernald and other leading plant taxonomists, Marie-Victorin was called upon in 1920 to establish the botany department in the newly autonomous Université de Montréal ("l'Institut botanique"; on its early history and several of its faculty and students see Marie-Victorin 1941). He also qualified for a doctorate from that university, with a dissertation on the ferns of Québec. This was followed by similar treatises on the clubmosses, horsetails, gymnosperms, Liliflorae (= Liliales), and Araceae—groups in which conspicuous intraspecific variation and teratology are common — and by several lesser monographs.

Marie-Victorin had botanized extensively in the vicinities of Québec City and Montréal and had published several botanical papers before taking up his university post. He had also explored (in 1914) and published a flora of Témiscouata County, where Québec abuts New Brunswick and Maine. In 1917 he undertook his first major botanical expedition, to the island of Anticosti in the Gulf of St. Lawrence. The following year he went to Témiscaming and the vicinity of Lake Abitibi, along the boundary between northern Québec and Ontario. In 1921, 1922, 1935, 1936, and 1937 he botanized in the vicinity of Lac Saint-Jean.

In 1923, while exploring the Shickshock Mountains of the Gaspé Peninsula, Marie-Victorin suffered a heart attack that restricted him thereafter to shorter and less strenuous expeditions. Nevertheless, the following year he began some of his most significant field work. During the summers from 1924 through 1928 he conducted an intensive botanical exploration of Anticosti and the Mingan Islands in the Gulf of St. Lawrence, accompanied by frère Rolland-Germain and, in 1925, by père Louis-Marie (below) (see Marie-Victorin and Rolland-Germain 1969 for a detailed account of their field work). On these islands, characterized by harsh environments and by markedly contrasting bedrock within a small area, these botanists found many rarities, some disjunct populations of Cordilleran species, and some new taxa, including a diminutive grape-fern, *Botrychium minganense* Vict., named for the islands, but now known to range across North America. Other rare and disjunct species were found along the estuary at Cap-Rouge near Québec City.

In 1930 and 1931 Marie-Victorin botanized around the Bay of Chaleur, on both the Québec and New Brunswick shores; in 1933 and 1941 in the upper Ottawa valley and the vicinity of Lake Abitibi; in 1932, 1936, and 1937 around Georgian Bay and at other localities in the Great Lakes region of Ontario; in 1934 along the Ottawa River; and in 1936 and at the time of his fatal accident in 1944 in the Eastern Townships of Québec. From 1938 through 1944 he spent the winters studying the flora of Cuba.

In 1935, Marie-Victorin published his largest and most familiar work, *Flore Laurentienne*, an illustrated, descriptive flora and phytogeographic discussion of that portion of Québec within the watershed of the St. Lawrence River and Gulf. This is noted as having been the first flora to include chromosome numbers. Marie-Victorin's best-known monument, however, is the Jardin Botanique de Montréal, which he proposed in 1929, after extensive studies of botanical gardens in Europe, and on which he began work in earnest two years later.

Frère Rolland-Germain (né Louis Roland, 1881-1972, on whom see Legault 1973) was a native of France who became a secondary-school teacher in Longueuil, Québec, and later in Ottawa. Initially Marie-Victorin's mentor in botany, he became his associate on nearly all of his major field trips. After Marie-Victorin's death, Rolland-Germain continued work on *Flore de l'Anticosti-Minganie* (Marie-Victorin and Rolland-Germain 1969), which was seen through to publication by Ernest Rouleau (below) after Rolland-Germain's own health deteriorated.

Père Louis-Marie (né Louis Lalonde 1896-1978, on whom see Van den Hende 1979) was Marie-Victorin's student as an undergraduate and subsequently received his doctorate from Harvard under Fernald's supervision, with a dissertation on the systematics of *Trisetum*. He taught for many years at l'Institut Agricole d'Oka, in Oka, Québec, where his students included several prominent botanists of later years, some of whom are mentioned below, and he established a large herbarium (now at Laval). This included his own numerous specimens from many parts of Québec, especially from the vicinity of Oka and the mountains of the Gaspé Peninsula. He authored the *Flore-Manuel de la Province de Québec* (Louis-Marie 1931), a copiously illustrated book designed as a guide to plant identification, and several textbooks.

Another priest who contributed greatly to the knowledge of the Canadian flora was abbé Ernest Lepage (1905-1981, on whom see Morisset 1981), professor at l'École d'Agriculture in his native Rimouski, Québec, curé of the church in nearby Saint-Simon, and author of many taxonomic papers on *Betula*, *Carex* (including significant studies of hybridization), *Hieracium*, and other genera. From 1936 through 1942 Lepage concentrated on the bryophytes and lichens of Québec — the subject of his master's thesis at Laval — and on the flora of the Rimouski area and the Gaspé Peninsula. Then in 1943 he met père Arthème-Antoine Dutilly (1896-1973, on whom see Lepage 1973), who was "looking for a companion for his expedition along the Rupert River" in northern Québec. Dutilly's education had included courses in agriculture at Oka, while Louis-Marie was on the faculty. When he met Lepage he was director of the Arctic Institute of the Catholic University of America in Washington, D.C., which institute he had founded two years earlier. Previously he had been a teacher in an agricultural school and director of an experimental farm near Rougemont, Québec. Dutilly began his botanical collecting in 1933, while traveling on a mission boat on Hudson Bay. In 1934 and 1940 he botanized along the Mackenzie River, and in 1936 along the Coast of Labrador and west through Hudson Strait to Chesterfield Inlet. In that year he went to the Catholic University as a research associate. Dutilly and others from the university made further visits to Labrador, Hudson Bay, and Hudson Strait, including the south shore of Baffin Island, in 1937, 1938, and 1939; to the Mackenzie River, Victoria and Banks islands, and also to Alaska and Greenland in 1940; and again to Labrador, Baffin Island, and Hudson Bay in 1942.

Combining Dutilly's gift for organization and enthusiasm for northern exploration with Lepage's greater botanical knowledge, they explored and published on the flora of vast areas that had hitherto received little or no botanical attention (Map 8). Every summer from 1943 through 1963, except for the years 1947 through 1949 when they were in Alaska, Lepage and Dutilly went to northern Québec and Ontario, in most years concentrating on the

1	Cape Henrietta Maria	15	Moose River	27	Kenogami River
2	Lake River	16	Harricanaw River	28	Pagwa River
3	Ekwan River	17	Nottaway River	29	Missinaibi River
4	James Bay	18	Rupert River	30	Bell River
5	Attawapiskat	19	Eastmain River	31	Lake Mistassini
6	Fort Albany	20	Opinaca River	32	Larch River
7	Moosonee	21	Fort George River	33	Koksoak River
8	Rupert House	22	Roggan River	34	Fort Chimo
9	Eastmain	23	Richmond Gulf	35	Caniapiscau River
10	Vieux-Comptoir	24	Landsdowne House	36	Swampy River
11	Fort George	25	Fort Hope	37	Schefferville
12	Winisk River	26	Ogoki		
13	Attawapiskat River				
14	Albany River				

Marcel Jomphe, 7/95

MAP 8. Principal sites of botanical exploration by abbé Ernest Lepage, père Arthème-Antoine Dutilly, and Father Maximilian George Duman, 1943-1963, showing routes of expeditions in 1943, 1945, 1952, 1961, and 1963.

shores and islands of James and Hudson bays, especially the east shore of James Bay, and often ascending various rivers. A complete list of their expeditions has been compiled by Boivin (1983); only some of the lengthier expeditions of this period, and those most significant to published reports, are specifically noted here [and reflected on Map 8]. In 1943 they went from James Bay to Lake Mistassini via the Rupert River (rivière des Goélands); in 1945 they traveled by canoe from Richmond Gulf (Lac Guillaume-Delisle) on Hudson Bay across Ungava via Lac à l'Eau-Claire and the Koksoak River to Fort Chimo on Ungava Bay; in 1946 they explored the Harricanaw River southeast of James Bay; in 1952 they went up the Albany River from James Bay to Fort Hope, thence via lesser rivers and portages to Lansdowne House, and down the Attawapiskat River to James Bay. In 1957, 1958, and 1960 they explored rivers flowing north from the Canadian National Railways line between Senneterre, Québec, and Pagwa River, Ontario, including lengthy stretches of the Bell, Harricanaw, Missinaibi, Pagwa, and Kenogami rivers; in 1959, while Lepage was leading field trips for the International Botanical Congress, Dutilly botanized on Banks and Victoria islands; in 1961 they traveled from Schefferville north to Fort Chimo on the Koksoak River near its mouth into Ungava Bay; in 1962 Dutilly explored the Winisk and Ekwan rivers of northern Ontario; and in 1963 they went by canoe from Schefferville to the Gulf of St. Lawrence (Boivin 1983). On several of these expeditions they were accompanied by Father Maximilian George Duman (1906-1990, on whom see Thompson 1991), of St. Vincent College in Pennsylvania, who had received his doctorate in botany from the Catholic University. Other botanists, listed by Boivin (1983), also participated in some of these expeditions. (On the specimens from these expeditions see Boivin 1983 and Tucker et al. 1989.)

Another noted québécois botanist, but in this case a layman, was Marie-Victorin's student (Joseph-Jules-Jean-) Jacques Rousseau (1905-1970, on whom see Pomerleau 1971). Rousseau's earlier botanical contributions included taxonomic studies of *Astragalus* and several other "difficult" genera and a survey of the intertidal vegetation of the Gulf of St. Lawrence. In 1928, 1931, and 1939 he botanized on the Gaspé Peninsula; in 1929 along the Restigouche and Matapédia rivers on both sides of the Québec-New Brunswick border; in 1930 in Nova Scotia and on the Magdalen Islands; and in 1940 and 1942 on Anticosti. In 1944, accompanied by (Joseph-Albert-) Ernest Rouleau (1916-1991, on whom see Lamoureux 1986, 1991a,b, *in* Rouleau and Lamoureux 1992) of l'Université de Montréal, he went to Lake Mistassini. During the next seven years he explored various floristically unknown regions of northern Québec — along the George River from Ungava Bay to Lac Hubbard in 1947; across the Ungava Peninsula from Hudson Bay to Ungava Bay via the Kogaluk and Payne (Arnaud) rivers in 1948; and up the Koroc River from Ungava Bay east to its headwaters in the Torngat Mountains on the Labrador border in 1951. Especially productive botanically was his expedition in 1949 to the remote Monts Otish, about 180 km northeast of Lake Mistassini. In addition to numerous floristic notes, Rousseau (1968) published a major treatise on the vegetation of the Ungava Peninsula. He is also credited with assuring the survival and continued development of the oft-embattled Jardin Botanique de Montréal after the death of its founder. Subsequently he served as a faculty member at l'Université de Montréal, as director of the Human History Branch of the National Museum of Canada, and ultimately as director of research at the Centre d'Études nordiques at l'Université Laval. He became noted for his contributions to botanical history, nomenclature, ecology, and especially ethnobotany and anthropology. A by-product of his work in the last-named fields was his "discovery" of the now-famous Annishnawbe artist Norval Morrisseau.

Also during the 1930s, Marcel Raymond (1915-1972, on whom see Boivin 1973), of the Jardin Botanique de Montréal, best known for his taxonomic studies of the Cyperaceae and Gesneriaceae, began a series of contributions to Québec floristics. He concentrated especially on the southwestern part of the province, including dolomitic areas near the international boundary noted for disjunct plant populations. This work culminated in his *Esquisse phytogéographique du Québec*, published in 1950. He often botanized with James Kucyniak (1919-1962, on whom see Crum 1965), a student of Marie-Victorin, employed at the Jardin Botanique de Montréal and primarily noted for his contributions to the bryophyte floristics of Québec. Another notable contributor to Québec floristics, with whom Raymond often botanized during the latter part of his career, was Lionel Cinq-Mars (1919-1973, on whom see Boivin 1982), of l'Université Laval, whose large herbarium is now at Laval (Boivin 1980).

Nicholas Vladimir Polunin (b. 1909), at the time a faculty member at Oxford, his alma mater, conducted floristic and ecological studies in the Canadian Arctic from 1931 through 1936, visiting Ellesmere, Devon, Baffin, and Southampton islands, Chesterfield Inlet on the west shore of Hudson Bay, northern Québec and Labrador, islands off these coasts, and portions of the interior of the Northwest Territories. This work culminated in a manual of the vascular plants of the Canadian Eastern Arctic (Polunin 1940), containing descriptions of several new taxa (mostly of infraspecific rank) and extensive taxonomic notes. Polunin

Alf Erling Porsild on aircraft, arctic field trip, IX International Botanical Congress (Montréal), 1959 (photograph by H. M. Raup; previously published in The Canadian Field-Naturalist 92: 298 [1978]).

(1959) subsequently published an illustrated flora of the entire circumpolar region, as well as many papers on arctic and subarctic phytogeography and ecology. His later academic career included a professorship at McGill University from 1947 to 1952, followed by similar positions in Iraq, Switzerland, and Nigeria (Stafleu and Cowan 1983).

In 1936, three years after Malte's death, the position of Chief Botanist at the National Museum was filled by Alf Erling Porsild (1901-1977, on whom see Soper and Cody 1978). Porsild, a native of Denmark, came to Canada in 1926 from the Danish Arctic Station on Disko Island, Greenland, where he had been assistant botanist, and was placed in charge of reindeer-grazing investigations. During the next ten years he collected thousands of botanical specimens in the Northwest Territories, "from the Richardson Mountains west of the Mackenzie River delta eastwards to the Coppermine River, about Great Bear Lake, and...to the central District of Keewatin." Porsild remained Chief Botanist at the National Museum until his retirement in 1967, except from 1940 to 1943 when he served as Canadian consul in Greenland. Regions in Canada in which he botanized included Labrador in 1937; the Yukon Territory (discussed below) in 1944 and 1970; the Alberta Rockies in 1945, 1946, 1951, and annually from 1955 through 1960; Banks and Victoria islands in 1949; Axel Heiberg Island, still farther north, in 1953; and the Hudson Bay Lowlands in 1956 and 1957. The many new taxa named and described by Porsild have been listed by his biographers (cited above).

(Väinö) Ilmari Hustich (1911-1982, on whom see Ahti 1983), of Helsinki, Finland (during the latter part of his career professor of economic geography at the Swedish School of Economics in that city), collected numerous botanical specimens while conducting ecological studies in Labrador and adjacent northern Québec from the 1930s through the 1960s. In 1963 he published a "preliminary inventory" of the known vascular plants of east-central Labrador.

A few additional individuals who were active before World War II should be mentioned here. Agnes Marion Ayre (1890-1940), an amateur botanist and artist of St. John's, collected Newfoundland plants during the 1920s and 1930s. Her specimens became the foundation of the herbarium of the Memorial University of Newfoundland, now named for her (Scott 1980). Numerous specimens were collected in Manitoba from 1916 to 1950 by Charles William Lowe (1885-1965, on whom see Carl 1969), while he was a faculty member at the University of Manitoba. Lowe compiled a list of the vascular plants of the province, published in 1943. William Pollock Fraser (1867-1943), of the University of Saskatchewan, noted primarily as a mycologist, is also to be credited with significant contributions to the knowledge of the vascular flora of Saskatchewan, especially in the area north of Prince Albert, and to the university's herbarium, which is now named for him (Craigie 1944). Probably the greatest individual collector of Alberta plants was William Copeland McCalla (1872-1962, on whom see Porsild 1964a), whose activities spanned several eras in botanical history. He began his herbarium in the 1890s, when he was a fruit-grower in St. Catharines, Ontario, but it was after he moved to Alberta, where he served as a teacher and school librarian, and especially after his retirement in 1938 that he was most active in floristic exploration. Gérard Gardner (1897-1988), was professor of natural sciences at the École des hautes Études commerciales, Université de Montréal, from 1927 to 1963, and founded its Centre de Recherches arctiques. He explored northern Canadian sites from Newfoundland and Labrador to the western shore of Hudson Bay almost annually during the 1930s and sporadically until ca. 1970, and published several papers on the plants (J. Cayouette, personal communication in 1989; unpublished résumé from École des hautes Études commerciales, kindly sent by S. G. Hay in 1993). The greatest part of his numerous botanical specimens became a major addition to the herbarium of Laurentian University, Sudbury, Ontario, with his earlier collections being at Laval (Boivin 1980).

After World War II: Professional botanists increase in numbers; Exploration of remote areas; Major floras written

After World War II the number of individuals directly engaged in floristic studies in Canada soared, as did the number of botanists who incidentally collected specimens that contributed to floristic knowledge. More universities offered courses and graduate programs in systematic botany, at least for a time, and both the National Museum and the Department of Agriculture (now designated Agriculture Canada) increased their botanical staffs. Cody et al. (1986) have recorded the dramatic increase in the size of the herbarium of the Department of Agriculture after World War II, under the directorship of Harold Archie Senn (b. 1912), head of the Botany Unit from 1951 to 1959 and the first head of the Plant Research Institute from 1959 to 1960. By 1951 there were ten systematic botanists on the staff. Also, a new generation of naturalists' clubs had arisen, beginning slowly in the late 1930s and increasing rapidly in the environmentally conscious 1960s, no longer emphasiz-

ing private collections but often interested in serious floristic investigations.

Organizational and name changes affecting the National Museum may be noted here. After many years in the Department of Mines and Resources (departmental name varied), and shorter periods in the Department of Northern Affairs and National Resources and the Department of the Secretary of State, the National Museums of Canada became a crown corporation in 1968. The National Museum of Natural Sciences, including the National Herbarium, was one of its component museums. In 1990 the National Museums corporation was dissolved, and its natural sciences component, reconstituted as the Canadian Museum of Nature, became a crown corporation reporting initially to the Minister of Communications and presently to the Minister of Canadian Heritage.

Obviously it would not be feasible to mention in this paper many respected professional and amateur botanists whose contributions, had they been made in an earlier era, would have earned them a stellar place in Canadian floristic history. The often difficult decisions as to who should be mentioned in the present paper have required consideration of such criteria as the number of specimens collected (as indicated by available statistics); the significance of the respective individuals' discoveries in relation to rare species and to areas not otherwise explored floristically; the thoroughness of their investigations, if they were undertaking a floristic study of a particular area; the quality of their data; and the quantity and quality of their floristic publications. In the following paragraphs, emphasis has been placed on those who have written floras for a whole province or a major portion thereof, or whose explorations stand out above all others' as sources of floristic data for areas of comparable extent; and those who have established or been the principal contributors of specimens to herbaria listed in *Index Herbariorum*. Full names, life spans, and biographical citations are given only for those deceased at the time of this writing. Also, only studies of the vascular flora are noted below. Whereas in the past bryophytes, lichens, and, in coastal regions, macroscopic algae were often collected and sometimes published upon jointly with vascular plants, research on the non-vascular flora has had an increasingly separate history during the twentieth century, concomitant with the increased professionalization of, and specialization in, the biological sciences. Post-1900 floristic exploration that concentrated on the non-vascular plant groups is not within the scope of the present paper. It is to be hoped, therefore, that other botanists will contribute histories of non-vascular plant exploration in Canada. Recently published histories of mycology in Canada (Estey 1994a,b), although their coverage is not restricted to exploration and collecting, include surveys of these topics.

Ernest Rouleau (above) explored Newfoundland botanically for 22 years and made some 13 000 plant collections in that province (Lamoureux 1986, in Rouleau and Lamoureux 1992). He published three editions of a list of the vascular plants of the province, including Labrador, plus Saint-Pierre et Miquelon, the latest in 1978, and an atlas, completed after his death by Gisèle Lamoureux (Rouleau and Lamoureux 1992). The herbarium at Gros Morne National Park in western Newfoundland consists largely of specimens collected by Stuart G. Hay and André Bouchard, of l'Université de Montréal and the Jardin Botanique, respectively, who have conducted extensive field work in this and other floristically interesting areas of Newfoundland (as well as in Québec) since the early 1970s, their earlier work in collaboration with Rouleau. In recent years they have been joined by Luc Brouillet, also of l'Université de Montréal (Rouleau and Lamoureux 1992). At the Botanical Garden of the Memorial University of Newfoundland (originally Oxen Pond Botanic Park), founded in 1971, Peter J. Scott has begun work toward a provincial flora.

A descriptive flora of Nova Scotia by A. E. Roland, of the Nova Scotia Agricultural College, Truro, was published in parts from 1944 through 1947; a second edition, coauthored by E. C. Smith of Acadia University, appeared in 1966-1969. David S. Erskine, a student employed by the Canada Department of Agriculture, did field work in Prince Edward Island in 1952 and 1953, and compiled a list of the vascular plants of that province, with distribution maps, published in 1961. This was reprinted in 1985 with additions and corrections by Paul M. Catling of the Biosystematics Research Institute (better known in the present context for his contributions to Ontario floristics, and also for studies of the systematics and ecology of Canadian orchids) et al. The latest addition to the Atlantic floras is *The Flora of New Brunswick* by Harold R. Hinds of the University of New Brunswick, published in 1986. This flora, representing considerable field work by its author and by Homer J. Scoggan (below), Patricia Roberts-Pichette, and other recent botanists, as well as earlier studies, includes keys, distribution maps, and illustrations of most of the species.

For Québec, Marie-Victorin's *Flore Laurentienne* was reprinted in 1964, with new material added by Rouleau, and in 1995 with additions by Live Brouillet and Isabelle Saucier. A flora of the Gaspé Peninsula was produced by Homer John Scoggan (1911-1986, on whom see Shchepanek 1987) of the National Museum of Canada in 1950. *Géographie Floristique du Québec/Labrador* (1974) by Camille Rousseau of l'Université Laval is a phytogeographic treatise. Although by no means a complete list of the flora, it serves many of the functions of such a manual, having notes on the ranges of the majority of the

native species as well as numerous distribution maps. The flora of the Eastern Townships, the hills of which harbour many uncommon and disjunct species, some on serpentine outcrops, has been intensively studied by Samuel Brisson (1918-1982) and other faculty members and students at l'Université de Sherbrooke.

All of Québec north of 55° has been covered in a floristic project directed by Pierre Morisset and Serge Payette, both of l'Université Laval, with other major participants in the field work having included Marcel Blondeau, Jean Deshaye, Jacques Cayouette, Linda Dion, and Robert Gauthier. At the time of this writing, their individual contributions, covering smaller areas within northern Québec, comprise issues of *Provancheria* from number 15 to number 24, with the complete flora existing only in manuscript. Another floristic study of a large portion of Québec is the "Flore du Saguenay" by Richard Cayouette (1914-1993, on whom see J. Cayouette 1994a,b), incomplete when its author died but represented in part by papers in *Le Naturaliste canadien* on some plant families. (On this project see J. Cayouette 1994b). The area covered encompasses the vicinity of Lac Saint-Jean and the Saguenay River, and the watershed of the St. Lawrence as far northeast as 65°40′W. Collections for this project, by Richard and Jacques Cayouette, Lionel Cinq-Mars, Samuel Brisson, and others listed by Jacques Cayouette (1994b) comprise much of the herbarium of the Québec Ministère de l'Agriculture, of which the senior Cayouette was curator until his retirement in 1979 (J. Cayouette, personal communication in 1989).

Although its origins were much earlier, the herbarium of the University of Guelph (Ontario Agricultural College before 1964) was much expanded after World War II by faculty members including Frederick Howard Montgomery (1902-1978, on whom see Britton and Alex 1978), whose interests included naturalized species and the Waterloo County flora, and more recently Jack F. Alex (at the Regina [Saskatchewan] Laboratory, Canada Department of Agriculture, until joining the Guelph faculty in 1968), who concentrated especially on agricultural weeds. Among those who added greatly to the herbarium at the University of Toronto (now at the Royal Ontario Museum) during the 1950s and/or 1960s were the faculty members James H. Soper (mentioned elsewhere in this paper in several contexts) and James E. Cruise (who subsequently became director of the Royal Ontario Museum), the latter having botanized especially in Norfolk County. Others who collected especially large numbers of specimens during this period included Roland Ernest Beschel (1928-1971, on whom see Smallman et al. 1991, p. 126; Kingston region and Arctic regions), an ecologist at Queen's University, Lulu Odell Gaiser (1896-1965, on whom see Moore and Grant 1965; Lambton County and the Bruce Peninsula), a pioneer in cytotaxonomy, at McMaster University until 1949, later at Harvard University and active in floristic study after her retirement; and Aleksander Tamsalu (1891-1960, on whom see Lord 1980 and Pringle *in press*; Hamilton region), of the Royal Botanical Gardens. More recently, the Erindale Campus of the University of Toronto, in Mississauga, has become another significant centre of research and graduate education in systematic botany, under the leadership of Peter W. Ball. Its now-large herbarium was founded in 1969 with a donation of the private collection of Alan Freeth Coventry (1888-1973, on whom see Mayall 1974), better known for his distinguished record of contributions in zoology, biological education, and conservation (Crins 1985).

Several projected floras of Ontario have come to naught, but in 1949 James H. Soper, then a faculty member at the University of Toronto, listed the vascular plants of the province "south of the Canadian Shield," i.e., south of an irregular line from the southeastern corner of Georgian Bay to the eastern end of Lake Ontario and including the Manitoulin Archipelago. The Clay Belt, extending from ca. 75°W in Québec (near Chibougamau) to ca. 89°W in Ontario (north of Lake Nipigon) and occupying the site of glacial Lake Ojibway, was in 1958 the subject of a flora by William Kirwan Willcocks Baldwin (1910-1979). Baldwin, of the National Museum, collected thousands of specimens from this region and also from the prairies and subarctic Canada (Soper and Bousfield 1982). In more recent years John L. Riley, another collector of a very large quantity of specimens, has conducted extensive studies of the vegetation and flora of the vast James Bay Lowlands. With Sheila M. McKay (subsequently McKay-Kuja), he has authored a treatise on its plant communities and phytogeography (Riley and McKay 1980). Riley (1989), with the aid of numerous "contributors," has also prepared a checklist of the vascular plants of the Ontario Ministry of Natural Resources "Central Region" of southern Ontario, from eastern Lake Erie to the southern end of Georgian Bay, noting the presence of the respective species in seven subdivisions of this region. A floristic list for the Ontario portion of the watershed of Lake Superior has been compiled by James H. Soper, Claude E. Garton, and David R. Given (1989), based on explorations of certain areas during the 1930s by T. M. C. Taylor (below), Robert Christie Hosie [1896-1971] et al., then of the National Museum (later with the Canadian Forestry Service), and on the authors' own extensive field work. Garton, in particular, should be noted for his botanical exploration of the Thunder Bay District of northern Ontario and for having founded the herbarium at Lakehead University (Noble 1985).

J. K. Morton and Joan M. Venn of the University of Waterloo, who had already written floras of the Manitoulin and Tobermory islands of Lake Huron, representing extensive field work of their own, have compiled a floristic list for the entire province. This list, published in 1990, is remarkable for the authors' thorough survey of the literature and investigation of questionable reports, and includes a large number of newly adventive species discovered by the authors and others.

Another important reference on the Ontario flora is *Grasses of Ontario*, initiated by William G. Dore of the Biosystematics Research Institute and completed with the aid of John McNeill, then also at the Biosystematics Research Institute, later at Ottawa University, the Royal Botanic Garden, Edinburgh, and, at the time of this writing, director of the Royal Ontario Museum. Dore's contributions to Canadian floristics also include ca. 30 000 herbarium specimens (Boivin 1980: *passim*) from Ontario, Québec, and the Maritime and Prairie provinces, as well as numerous papers on plant distribution, systematics, and botanical history. There are also several treatises, written by individuals affiliated with several institutions (and in some cases with amateur collaboration) covering some other families and large genera as they occur in Ontario.

A list of county and regional floras for southern Ontario completed or in progress as of 1983 has been compiled by Steve Varga (1983), providing the names of important present-day contributors to floristic knowledge too numerous for direct recognition in the present paper. The obsolescence of this list inevitably was rapid, because of the many such projects initiated in recent years, reflecting widespread concern for rare species and the protection of ecologically sensitive areas. More recently, a list of county and regional floras for the southernmost part of the province (the "Carolinian Zone") has been published by Varga and Allen (1990).

A very incomplete list of additional career and amateur botanists who have contributed significantly to the floristic knowledge of Ontario since ca. 1970, based on the criteria noted above, should include Wilfred Botham (1908-1989, on whom see Oldham 1990; Essex County), Daniel F. Brunton (Algonquin Provincial Park and Ottawa Valley), William J. Crins (Regional Municipality of Halton and many other localities), John M. Gillett (Ottawa-Hull region), Robert Hainault (Kingston region), James P. Goltz (Muskoka District), Joseph W. Johnson (Bruce Peninsula), Paul F. Maycock (Carolinian Zone), Deborah A. Metsger and Royal Ontario Museum colleagues (remote areas of northwestern Ontario), Mary I. Moore (Ottawa Valley and Algonquin Provincial Park), Michael J. Oldham (Essex and other southwestern Ontario counties; also studies of provincially rare species), Anton A. Reznicek (Long Point [Regional Municipality of Haldimand-Norfolk], Simcoe County, Algonquin Provincial Park, and many other areas), Eleanor Grace Skelton, née Spaulding (1908-1989, on whom see McKay-Kuja 1986) and Emerson W. Skelton (Haliburton County), William G. Stewart (Elgin and adjacent counties), Donald A. Sutherland (Leeds County and several other areas), Jocelyn M. Webber (Regional Municipality of Peel), and R. Emerson Whiting (Muskoka District). Although in this paragraph the names of individuals have been associated with the areas of their most significant botanizing in relation to quantities of specimens and/or to publications, some of those mentioned have also made significant contributions to floristic knowledge in other regions of Ontario or in other provinces and territories, as in the case of J. M. Gillett, who also studied the flora at several boreal sites. Paul M. Catling, William J. Cody, Sheila M. McKay-Kuja, John L. Riley, James H. Soper, and Steve Varga, some of whose other contributions are noted elsewhere in this paper, are also among those who have botanized extensively in many parts of Ontario. Many additional names of botanical explorers, some of whose contributions to floristic knowledge have been of only slightly less magnitude, can be found in the acknowledgments and literature citations in county and regional floras and in such compilations as those by Boivin (1980), Varga (1983), Brunton (1986), and Varga and Allen (1990).

In populous areas throughout Canada, floristic studies in recent years have often focused on "environmentally sensitive areas," with the objective of identifying and protecting natural areas that support stands of rare species from destructive developments. This trend is especially evident in Ontario, because of its extensive urban development and because the Canadian ranges of many species are restricted to the narrow zone of Carolinian vegetation, where much of this urban development has occurred. The traditional corps of academics and amateurs has been joined by a new contingent, the ecological consultants, some of whom are among the individuals mentioned in the preceding paragraph. While some recent studies have been marred by haste, implausible identifications and/or uncritical acceptance of previous identifications, or lack of documentation, many have been exemplary in their scholarship. These studies have provided much useful information, especially by chronicling changes in the flora as native species of restricted habitats decline and exotic species become naturalized.

Descriptive floras are available for two of the three Prairie Provinces. Manitoba is covered by a provincial flora by Homer J. Scoggan (above), published in 1957, incorporating the results of Scoggan's extensive field work in the province from 1948 through 1953. A flora of Alberta, by Ezra

Henry Moss (1892-1963, on whom see Bird 1963) of the University of Alberta, was published in 1959. In 1983 it was succeeded by a new edition, revised and updated by John G. Packer of the same university, incorporating *inter alia* the results of Packer's many studies of the distribution and systematics of Rocky Mountain and northern Alberta plants. There is also a descriptive flora of Waterton Lakes National Park in Alberta by Job Kuijt of the University of Lethbridge. Only a list has been published (in 1957-1959) for Saskatchewan, but it does contain copious data on distribution. This was compiled by August Julius Breitung (1913-1978, on whom see Harms 1988, 1989), who explored the province's flora for many years. Earlier, Breitung had authored a paper on the vegetation and flora of the Cypress Hills of Saskatchewan and Alberta, with a list of the vascular plants, and a flora of Waterton Lakes National Park. Vernon L. Harms and his colleagues at the University of Saskatchewan have conducted extensive floristic investigations in the province in recent years, especially in the northern part. A provincial flora by Harms is in progress at the time of this writing.

In addition, (Joseph-Robert-) Bernard Boivin (1916-1985, on whom see Cody and Cayouette 1986 and McNeill 1986) authored *Flora of the Prairie Provinces*, published in parts from 1967 through 1981 (with a volume containing references and an index awaiting publication at the time of this writing). Although Boivin did field work in these provinces during eight seasons between 1946 and 1960, while employed first at the National Museum and later at the Department of Agriculture in Ottawa, often in association with colleagues from these institutions, he characterized himself as an "herbarium botanist." The majority of the records represented in this flora were compiled from specimens seen in Ottawa herbaria, on loan, or during his visits to nearly every sizable herbarium in Canada, while working on his *Survey of Canadian Herbaria* (below). Although one may be distracted by Boivin's own higher-level classification of the angiosperms, much in the Hutchinsonian tradition, and by his occasional departures from mainstream species concepts, this flora is a valuable reference not only for identification but also, like many works by its author, for information on plant distribution and botanical history.

At the University of Regina, in Saskatchewan (University of Saskatchewan, Regina Campus until 1974; herbarium founded as that of the affiliated Saskatchewan Museum of Natural History), the principal contributor of specimens during the 1960s and 1970s was George F. Ledingham, a faculty member in botany, interested in the systematics of Fabaceae as well as in Saskatchewan floristics. Ledingham also contributed numerous specimens of Saskatchewan plants to the herbarium of the University of Saskatchewan at Saskatoon. Another major contributor of specimens to the latter herbarium during this period was John H. Hudson, whose collections concentrated especially on Cyperaceae (Boivin 1980) but also documented reports of new Saskatchewan records for species in many other flowering-plant families, published in *The Blue Jay*.

In Alberta, the principal contributor of specimens to the then-newly founded herbarium at the University of Calgary during the 1960s and 1970s was faculty member Charles D. Bird. Although lichens and bryophytes constituted the greater part of his contribution of over 35 000 specimens, substantial numbers of vascular plants were also included. Bird's specimens were collected mostly in southern Alberta, including some that represented notable records for the Cypress Hills. He also botanized in areas of the continental and insular portions of the Northwest Territories that were poorly known floristically, as well as in Saskatchewan, Manitoba, and British Columbia.

Three amateur botanists in the Prairie Provinces established significant herbaria consisting largely of their own specimens and have published many notes in *The Canadian Field-Naturalist* and *The Blue Jay*. These are George Harrison Turner (1877-1970, on whom see Bird 1971) of Fort Saskatchewan, Alberta; Bernard de Vries of Fort Qu'Appelle, Saskatchewan, whose specimens became the herbarium of the Fort Qu'Appelle Naturalists' Society in 1959, later transferred to the University of Regina; and Walter (né Vladimir) Krivda of The Pas, Manitoba, said by Boivin (1980) to have had the largest private herbarium in Canada as of 1980.

Other botanists in the Prairie Provinces appropriate to mention here include Jennifer M. Shay, née Walker, of the University of Manitoba, who collected most of the specimens in the herbarium of the university's field station at Delta Marsh in connection with her studies of marsh ecology; Janet R. Dugle, who established the herbarium at the Atomic Energy of Canada's Whiteshell Reserve, Pinawa, Manitoba (this herbarium now incorporated into that of the Manitoba Museum of Man and Nature); Karen L. Johnson, of the Manitoba Museum of Man and Nature, who has botanized at Churchill and elsewhere in Manitoba; Robert T. Ogilvie, who was at the University of Calgary before moving to Victoria (below), and Beryl M. Hallworth of Calgary, both of whom collected large quantities of southwestern Alberta specimens; and J. Derek Johnson, of the Northern Forestry Centre, Forestry Canada, Edmonton, who collected numerous specimens in Alberta and the Northwest Territories, mostly in the boreal forest regions, and smaller quantities in Manitoba and Saskatchewan. William J. Cody, whose floristic work in Ontario, the Yukon Territory, and the Northwest Territories has been

James Alexander Calder botanizing in the mountains of British Columbia, 1956 (photograph by Jack Parmelee; previously published in The Canadian Field-Naturalist 105: 585 [1991]).

noted elsewhere in this paper, has also contributed significantly to floristic knowledge in Manitoba and elsewhere in the Prairie Provinces.

A supplement to J. K. Henry's *Flora of Southern British Columbia* was published in 1947 by John William Eastham (1879-1968, on whom see Beamish 1969), Provincial Plant Pathologist. Although primarily interested in plant pathology and mycology, especially myxomycetes, Eastham also collected ca. 10 000 specimens of vascular plants.

The Queen Charlotte Islands, ca. 100 km from the British Columbia mainland and ca. 55 km west of the coastal islands, support a flora rich in endemic taxa, for which there is an elegant manual by James Alexander Calder (1915-1990, on whom see Cody and Cayouette 1992) and Roy L. Taylor. A companion volume on chromosome numbers was prepared by Taylor and Gerald A. Mulligan. All three authors were then at the Department of Agriculture's Plant Research Institute in Ottawa. Taylor later served as director, successively, of the University of British Columbia Botanical Garden and the Chicago Botanic Garden, and at the time of this writing, as director of the Rancho Santa Ana Botanic Garden in Claremont, California.

For the whole province of British Columbia, a list of the vascular plants, with abbreviated distributional data, was compiled in 1977 by Roy L. Taylor and

Bruce MacBryde. Taylor was then at the University of British Columbia Botanical Garden, and MacBryde, who had also been at the U.B.C. Botanical Garden, was at the Office of Endangered Species, U.S. Fish and Wildlife Service. The dedication acknowledged "scholarly devotion to the flora of British Columbia" by Calder, who during the 1950s and early 1960s had collected extensively for an inventory of the province's flora (not completed) sponsored by the Department of Agriculture, and had published many papers on British Columbia plants, as well as being known as an authority on Canadian *Carex*. This was followed by a four-part vascular flora of British Columbia by George W. Douglas, Gerald B. Straley, and Del Meidinger (Douglas et al. 1989-1994), of the British Columbia Conservation Data Centre (Ministry of Environment, Lands and Parks), the University of British Columbia, and the British Columbia Ministry of Forests, respectively, all of whom have done extensive field work in various parts of British Columbia. This work provides keys and distributional information but does not include descriptions.

In addition, the British Columbia Provincial Museum (now the Royal British Columbia Museum) has published a fern flora for British Columbia (Taylor 1973) by Thomas Mayne Cunninghame Taylor (1904-1983, on whom see Brayshaw 1984), another noted student of the province's flora, who previously authored a "preliminary list" of its vascular plants (Taylor 1966) and a fern flora of the Pacific Northwest (Taylor 1970), covering Alaska, the Yukon Territory, British Columbia, Washington, and Oregon. The Museum has also issued several smaller books by various authors, each dealing with one or a group of plant families in the province, significantly supplementing the flora by Douglas et al. (1989-1994), and especially useful before the publication of that work, in that they include descriptions, illustrations, and discussions of taxonomic problems. "An indefinite southern fringe of British Columbia" is covered by *Vascular Plants of the Pacific Northwest* by University of Washington professor C(harles) Leo Hitchcock (1902-1986, on whom see Denton 1986) et al. and by the condensed version, *Flora of the Pacific Northwest* (Hitchcock et al. 1955-1969; Hitchcock and Cronquist 1973).

Much was contributed to the floristic knowledge of British Columbia by Vladimir Joseph Krajina (1905-1993, on whom see Česka 1993), who was also at the University of British Columbia, during his extensive studies of plant communities and ecosystems, which research was largely responsible for the establishment of the province's system of ecological reserves. Other British Columbia botanists active since 1960 appropriate to mention for their extensive plant collections and publications on the flora include Adam F. Szczawinski, T. Christopher Brayshaw, Robert T. Ogilvie, and Adolf Česka, all of the Royal British Columbia Museum (although some retired before the name change), and Katherine I. Beamish of the University of British Columbia.

The construction of the Canol Road from the Alaska Highway to the Mackenzie River opposite Norman Wells provided access to botanically unexplored regions for a party from the National Museum of Canada led by Alf Erling Porsild (above) in 1944. Porsild's (1951) report on this expedition was the major reference specifically on the Yukon flora for many years. It was supplemented in 1975 by another work by Porsild on the central Yukon, based on botanizing made feasible by the construction of the Dempster Highway from the vicinity of Dawson to Inuvik, Northwest Territories, on the Mackenzie delta. The principal collector represented in this publication was Robert Thorbjørn Porsild (1898-1977, brother of A. E. Porsild), at that time under contract to collect botanical specimens for the National Museum, having retired from operating a lodge at Johnson's Crossing, Yukon Territory. He had previously been active in biology on Disko Island (above) with his father and brother. (Ironically, while Robert T. Porsild studied botany, hoping to succeed his father, M. P. Porsild, as director of the Danish Arctic Station, his brother Erling had been preparing for a career as a merchant.) In 1966 and 1968 R. T. Porsild botanized in the Ogilvie Mountains and in 1967 near Mayo, "where special attention was paid to the...alpine floras of Keno Hill and Mount Haldane." Both Porsilds visited these areas and others farther north along the highway in 1970, contrasting the floras of calcareous and non-calcareous sites.

Eric (né Oskar Erik Gunnar) Hultén (1894-1981, on whom see Löve 1981), peripatetic retired director of the botanical division of the Swedish Museum of Natural History at Stockholm, also studied the Yukon flora during the 1960s, supported by the Arctic Institute of North America. His own collection sites (mapped in Hultén 1968: xviii) include several near Dawson and along the southern part of the Dempster Highway; three in the Peel River watershed of eastern Yukon between ca. 64°N and the Arctic Circle; and one in the northern tip of the Territory. Hultén's works already included several classic volumes on arctic biogeography and the floras of regions on both sides of the Bering Strait. In 1968 he published *Flora of Alaska and Neighboring Territories*, a descriptive manual with keys, illustrations, and maps, covering Alaska, the Yukon Territory, and portions of British Columbia and the Northwest Territories. The Yukon Territory is also covered by *Anderson's Flora of Alaska and Adjacent Parts of Canada*, based on an earlier work (Anderson 1943-1952) by Jacob Peter Anderson (1874-1953, on whom see Pohl 1959), revised by Stanley L. Welsh (1974) of Brigham Young University. Welsh (1974) noted field work by himself and by Maxcine Morgan Williams along high-

ways in the southern part of the Yukon Territory, although most of their field work was in Alaska. Welsh, with J. Keith Rigby, also botanized extensively in the northern part of the Yukon Territory and in northern British Columbia (Welsh and Rigby 1971a,b). At the time of this writing a new flora of the Yukon Territory is being prepared by William J. Cody of the Centre for Land and Biological Resources Research, collector of numerous specimens in many parts of Canada and author of many taxonomic and floristic notes on Canadian plants. Cody's work in the Yukon was mostly conducted from 1980 through 1984, in areas from 60°N to the Arctic coast.

Erling Porsild's extensive exploration of arctic Canada led to the publication in 1957 of an illustrated flora, with keys and descriptions, covering the Canadian Arctic Archipelago. At the time of his death in 1977 he had nearly completed a similar (but larger) flora of the mainland portion of the Northwest Territories. His mantle was assumed by William J. Cody (above), who had been associated with him in this work since 1960. In the Northwest Territories Cody botanized in the vicinities of Yellowknife in 1948; Fort Smith, near the Alberta border, in 1950; Norman Wells, including sites on the east slope of the Mackenzie Mountains, and also Aklavik, in 1953; and Fort Simpson, on the Mackenzie River, in 1955. In 1957 and 1963 he explored the Mackenzie delta, going as far east as the Anderson River in 1957; in 1961 he followed the Liard River from the British Columbia border to the Mackenzie River; in 1966 he explored a large area east of the Slave River in the southeastern part of the District of Mackenzie; and in 1967, 1970, and 1971 he investigated the flora at numerous sites in the Mackenzie Mountains, between the Mackenzie River and the Yukon border (Porsild and Cody 1980, q.v. for the names of other participants on some of these expeditions). The flora, by Porsild and Cody was completed in 1980. Further floristic discoveries in the continental Northwest Territories have been reported by Cody and his associates in later papers.

George W. Scotter is another who made especially notable contributions to the floristic knowledge of the Northwest Territories in recent years. Although Scotter emphasized lichens and bryophytes in his botanical collecting and publications, he also contributed significantly to the knowledge of the vascular flora. While he was director of the Edmonton office of the Canadian Wildlife Service from the 1960s through the 1980s, and continuing after his retirement, he collected several thousand plants in many localities in the continental and insular Northwest Territories and in parts of Alberta, British Columbia, and the Yukon Territory. Scotter's published contributions on vascular plants include an annotated floristic list for Nahanni National Park, Northwest Territories, prepared in collaboration with W. J. Cody (above) and, in the supplement, with Stephen S. Talbot (Scotter and Cody 1974; Cody et al. 1979). Contributions to the floristic knowledge of the Northwest Territories by Charles D. Bird and J. Derek Johnson have been noted elsewhere in this paper.

The first list of vascular plants for all of Canada since Macoun's *Catalogue* was Bernard Boivin's *Énumération des Plantes du Canada*, published in parts in 1966 and 1967 and reprinted in a single volume in 1968. Although having the same peculiarities as *Flora of the Prairie Provinces*, it has proved to be a useful reference, perhaps as much or more as a botanical bibliography and history than for distributional data. The closest approach to a complete descriptive flora of Canada — the abortive plan of several earlier botanists — was achieved in 1978-1979 by Homer J. Scoggan (above), a veteran of field work across the country (Shchepanek 1987). His *Flora of Canada*, published by the National Museum of Natural Sciences, lists all the vascular plants then known to occur outside cultivation in Canada, with descriptions only of the families, but with keys to the genera and species, distributional data, and an abundance of literature citations, although generally only to 1967. (For initial impressions of this flora, see Pringle 1979 and Brunton 1981.) In the future, complete coverage of the Canadian vascular and bryophyte flora will be provided in the *Flora of North America North of Mexico*, the first two volumes of which have been published at the time of this writing, covering, respectively, introductory topics and the non-flowering vascular plants. Numerous specialists have been recruited to prepare the treatments of the families and genera. A history of this project, prepared by Nancy R. Morin, the editor-in-chief, and Richard W. Spellenberg (1993), was included in the first volume.

William J. Cody (above) and Donald M. Britton, the latter retired from the faculty of the University of Guelph, authored *Ferns and Fern Allies of Canada/Les Fougères et les Plantes Alliées du Canada*, a descriptive manual with maps and notes on chromosome numbers (Cody and Britton 1989). Also deserving mention are lists of the rare vascular plants of each province and territory, published by the National Museum of Natural Sciences as issues of *Syllogeus*. Their compilation has been headed by George W. Argus of the National Museum, who is also noted as a botanical explorer, especially of boreal Saskatchewan, and as an authority on the systematics of *Salix*.

Most conspicuously absent from the foregoing paragraphs on post-1945 botanists are the names of individuals whose contributions were primarily taxonomic or ecological rather than floristic, and those whose floristic studies concentrated on individual

species or genera. In partial compensation, publications are noted here that list numerous individuals who have contributed to the floristic knowledge of provinces or territories. The historical summaries for the north shore of the Gulf of St. Lawrence by St. John (1922); for the Lake Huron watershed of Ontario to 1900 by the present author (Pringle 1989); for the Northwest Territories by Simmons (1913), Polunin (1940), Porsild (1964b), and Porsild and Cody (1980); and for parts of the Yukon Territory by Porsild (1951, 1975) have already been noted. Similar historical accounts, covering at least the major events in floristic exploration and in some cases being considerably more thorough, have been compiled by Rouleau and Lamoureux (1992) for insular Newfoundland; Roland (1947) for Nova Scotia; Erskine (1961) for Prince Edward Island; Young (1986) for New Brunswick; Dutilly and Lepage (1945-1947, 1963) and Dutilly et al. (1954, 1958) for the James Bay watershed of Québec and Ontario and for the James Bay islands; Jacques Cayouette et al. for several areas in northern Québec, in the issues of *Provancheria* noted above; Baldwin (1958) for the Clay Belt of northern Ontario; Scoggan (1957) for Manitoba; Breitung (1957) for Saskatchewan; Harms et al. (1980) more recently for the northern part of that province; Moss and Packer (1983, including the historical review reprinted unchanged from the 1959 edition, and Packer's acknowledgments of more recent botanizing) for Alberta; Calder and Taylor (1968) for the Queen Charlotte Islands; Eastham (1947) for the southern half of British Columbia from the 1920s to the early 1940s; and Hultén (1940) for the entire Yukon Territory (and Alaska) up to 1940, with a map of all significant botanical collecting areas up to that time. It is no longer feasible for provincial floras to list the numerous individuals who have collected botanical specimens in populous areas or "cottage country," but many recent floras of smaller areas do have thorough historical accounts.

A list of the systematic biologists at Agriculture Canada, Ottawa, through 1986, with biographical data and summaries of their contributions, has been published by Cody et al. (1986). Major contributors of specimens to l'herbier Marie-Victorin, the herbarium of l'Université de Montréal, have been listed by Charbonneau (1994-1995), with brief biographical sketches of several.

Of the earlier bibliographic compilations, the most significant for the history of Canadian floristics are those by Bourinot (1895) and Adams et al. (1928-1951). Bourinot listed the published works by the members of the Royal Society of Canada as of 1894, among whom were most of the Canadian career scientists of the time mentioned in the present paper. Adams et al. listed all papers known to them that dealt with any aspect of Canadian plant geography broadly defined, regardless of the authors' nationality. In more recent years, Laird (1980) has compiled a natural-history bibliography for Newfoundland and Labrador; Catling et al. (1986) have produced a botanical bibliography for Nova Scotia, New Brunswick, and insular Newfoundland; and Douglas et al. (1983) have compiled a floristic bibliography for British Columbia. A similar bibliography for Ontario by Hodgins (1978), although more limited in scope, lists post-1930 publications, and a general bibliography on the Hudson Bay Lowlands by Haworth et al. (1978) includes a substantial section on the flora. Publications adding to the known flora of Manitoba subsequent to Scoggan's *Flora of Manitoba* have been listed by Catling and Brownell (1987). Natural-history bibliographies are also available for many smaller areas, including several urban areas in Ontario. As of this writing, the Canadian Botanical Association is compiling an ongoing bibliography and collection of floristic lists for all of Canada; this includes many unpublished lists and publications of limited distribution.

Boivin's (1980) *Survey of Canadian Herbaria* lists all herbaria in Canada, past and present, known to its author, including many not mentioned in *Index Herbariorum*. It provides copious information on their respective histories, principal collectors, and important publications for which they house the documentation. The names of numerous individuals appear in the index, as a means of locating the repositories of their specimens.

Closing Note

Such studies as those reported in the present volume are never complete, because additional people continue to contribute to floristic knowledge. As long as there remain opportunities for interesting floristic discoveries, historians will have opportunities and responsibilities to record the stories of these discoveries and the lives of those who made them.

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Appendix: Principal Repositories of Herbarium Specimens of Canadian Origin Collected and/or Studied by Persons Mentioned in this Paper

Standard references on the present repositories of herbarium specimens include *Index Herbariorum, Part 2*, comprising *Regnum Vegetabile* 2, 9, 86, 93, 109, 114, and 117; *Taxonomic Literature*, edition 2, cited in this paper as Stafleu and Cowan (1976-1988); Desmond (1994), for British and Irish botanists in Desmond's broad interpretation; and Boivin (1980), for specimens in Canadian herbaria. The very incomplete list presented here, which concentrates on the primary repositories of specimens collected by individuals and expeditions mentioned in the present paper, can greatly be supplemented by consulting those references, along with works recounting the history of floristic exploration in the regions respectively covered (especially Porsild and Cody 1980 and Pringle 1989, 1992), and the biographical works on the individual collectors. "Studied by," above, refers to nineteenth-century and earlier botanists in Europe; recent botanists who have worked on the floras of large areas, of course, have generally examined specimens in many herbaria. The citations of herbaria in this appendix indicate actual locations only; the status of permanent or extended loans and of collections filed or housed separately, and related technicalities that might require complex or delicate wording, have not been investigated. Abbreviations for herbaria follow Holmgren et al. (1990).

Agassiz, (J.) L. (R.) Specimens from Agassiz's expedition to Lake Superior, collected by C. G. Loring, Jr., et al., are at GH.

Albrecht, C. G. See Moravian missionaries.

Alex, J. F. Principal repositories of Ontario specimens OAC, Saskatchewan specimens DAO, DAS; duplicates are in several other herbaria.

Ami, H. M. CAN, MTMG

Amundsen, R. The principal repository for specimens from the *Gjøa* expedition is O; duplicates are at C.

Anderson, Jacob P. ALA, ISC; duplicates are widely distributed.

Anderson, James. MTMG

Anderson, James Robert. Principal repository V; smaller numbers at WS and elsewhere.

Anderson, Robert. See Arctic explorers 1818-1859.

Anderson, Rudolph M. Specimens collected by the southern party of the Canadian Arctic Expedition of 1913-1918 are at CAN; duplicates sent to H. T. Holm for identification, formerly at LCU, are now at CAN.

Andersson, O. F. See Nordenskjöld, (N.) O. (G.).

Arctic explorers 1818-1859. Botanical specimens from the arctic expeditions led by Ross in 1818 and by Parry in 1819-1820 were sent to Robert Brown of the British Museum, and are now at BM. The specimens collected by British arctic expeditions from 1821 through 1839, including the two land expeditions led by Franklin, were sent to W. J. Hooker, who based much of his *Flora Boreali-Americana* upon these specimens. In addition to receiving specimens from Royal Navy expeditions, Hooker was also the recipient of specimens from the arctic and subarctic regions collected by individuals employed by the Hudson's Bay Company or as surgeons on whaling vessels during this time, and studied the herbarium specimens from Douglas's privately financed expedition in western British North America. Specimens collected on arctic expeditions during the search for Franklin, 1847-1859, were studied by J. D. Hooker. The specimens studied by both Hookers are now at K, with duplicates distributed to BM, GH, OXF, and other herbaria.

Argus, G. W. CAN; his early specimens from Saskatchewan are at SASK.

Austin, H. T. See Arctic explorers 1818-1859.

Ayre, A. M. Her herbarium became the nucleus of NFLD.

Bachelot de la Pylaie, A. J. M. P

Back, G. See Hooker, W. J.; his specimens are also at BM.

Bailey, L. W. UNB

Baldwin, W. K. W. CAN
Ball, E. H. NSPM
Ball, P. W. Canadian specimens at TRTE.
Banks, J. His herbarium, including, inter alia, specimens collected by him in Newfoundland and Labrador and specimens sent to him by Moravian missionaries in Labrador and many other correspondents, became the original herbarium of the British Museum (Natural History), now part of BM.
Barnston, G. MTMG
Barnston, J. MTMG
Bassett, I. J. DAO
Beamish, K. I. UBC
Belcher, E. See Arctic explorers 1818-1859.
Bell, J. Principal repository of Lake Huron collections CCO.
Bell, R. Early specimens mostly at QK; later specimens at CAN.
Beschel, R. E. Canadian specimens at QK.
Billings, B. QK
Bird, C. D. Principal repository of vascular plants UAC; smaller numbers at WLP and other Canadian herbaria.
Blondeau, M. QFA; His own herbaria is private; duplicates are at QFA, DAO, etc.
Bodega y Quadra, J. F. de la. See Mociño, J. M.
Boivin, (J. R.) B. DAO, MT, TRT, QFA; duplicates are widely distributed.
Botham, W. CAN, DAO, LKHD, TRT
Bouchard, A. GMNP, MT, MTMG
Bourgeau, E. His specimens from British North America are at K; duplicates are widely distributed (but, having been distributed from K, likewise lack locality data).
Bowman, J. H. OAC; many specimens collected were collected with J. Dearness and bear Dearness's name.
Brayshaw, T. C. Principal repository of British Columbia specimens V; duplicates, earlier specimens from Ontario, and other specimens are at CAN and several other Canadian herbaria.
Breitung, A. J. His own herbarium and specimens collected while on staff with Agriculture Canada are at DAO; SASK is another major repository; duplicates are widely distributed.
Brenton, M. See Hooker, W. J.
Brisson, S. DAO, SFS, QUE MT
Britton, D. M. OAC
Brouillet, L. MT; GMNP is a significant repository for Newfoundland specimens; earlier specimens are at WAT and MTMG.
Brown, Robert (Campster). K
Brown, Robert (London). See Arctic explorers 1818-1859.
Brown, Robert (Perth). See McNab, J.
Brown, S. Principal repository for Canadian specimens GH.
Brunet, L. O. QFA
Brunton, D. F. His own herbarium is private; duplicates and other specimens are at APM, CAN, DAO, and many other herbaria.
Burgess, T. J. W. Specimens from the British North American Boundary Survey are at CAN and TRT; other specimens are at HAM, MTMG, and other Canadian herbaria.

Calder, J. A. DAO, V; duplicates are widely distributed.
Campbell, R. (H.B.C.) K
Campbell, R. (Montreal) MTMG
Carrier, J. C. MT
Catling, P. M. DAO; his earlier specimens are at TRT.
Cayouette, J. DAO, QFA, QUE.
Çayouette, R. QUE
Ĉeska, A. V
Cinq-Mars, L. His own herbarium is at QFA; DAO, MT, and QUE are other major repositories; duplicates are widely distributed.
Cleghorn, R. See Hooker, W. J.
Cochrane, A. F. I. See Hooker, W. J.
Cody, W. J. DAO; duplicates are widely distributed.
Collins, J. F. See Fernald, M. L.
Collinson, R. See Arctic explorers 1818-1859.
Cormack, W. E. LINN
Cosens, A. TRT
Coventry, A. F. TRTE
Crins, W. J. His own herbarium is private; duplicates and other specimens are at TRTE and several other Canadian herbaria.
Croft, H. H. TRT
Cruise, J. E. CU, TRT

Dalhousie, Lady. See Hooker, W. J.; duplicate specimens from Québec are at HAM; some specimens from Nova Scotia are at E.
Davidson, J. UBC
Dawson, G. M. CAN
Dawson, (J.)W. MTMG
Dearness, J. Most of his own herbarium (vascular plants) is at DAO; MT and OAC are other major repositories, the latter including the herbarium of the Entomological Society of Ontario; his specimens of fungi are at DAOM.
Dease, P. W. K
Deshaye, J. QFA
De Lisle, A. See Provancher, L.
de Vries, B. His own herbarium became the nucleus of the herbarium of the Fort Qu'Appelle Naturalists' Society, now at USAS; duplicates are at PMAE.
Dion, L. QFA, QFBE duplicates at DAO.
Dodge, C. K. His own herbarium is at MICH; duplicates are widely distributed.
Dore, W. G. DAO; duplicates are widely distributed in Canadian herbaria.
Douglas, D. See Hooker, W. J.
Douglas, G. W. V
Drummond, A. T. QK
Drummond, T. See Hooker, W. J.
Dugle, J. R. MMMN
Duhamel du Monceau, H. L. P
Duman, M. G. See Lepage, E.
Dutilly, A. A. See Lepage, E.

Eames, E. H. CONN; GH and NEBC are other major repositories; duplicates are widely distributed in United States herbaria, including Newfoundland specimens at MICH.
Eastham, J. W. Principal repository UBC; smaller numbers are at DAO, V.
Eastwood, A. *Salix* and other specimens collected in western Canada are at A and CAS; otherwise the principal repository of her specimens is CAS.
Erskine, D. S. DAO; NSPM is another major repository; duplicates are widely distributed.

Farr, E. M. PH
Fassett, N. C. Early specimens, notably those from his studies of estuarine vegetation in eastern Canada, are at

GH; later specimens, including those from the north shore of Lake Huron, are primarily at WIS; duplicates are widely distributed.

Fernald, M. L. The principal repository of his specimens is GH; duplicates are widely distributed. "See Fernald, M. L." in the present list refers to some of the other amateur and professional botanists, mostly associated with Harvard University, who accompanied Fernald on expeditions to Atlantic Canada.

Fletcher, J. His own herbarium became the nucleus of DAO; CAN is another major repository.

Fogg, J. M. See Fernald, M.L.

Fowler, J. QK; his early New Brunswick collections are at NBM; duplicates are at DAO, LKHD, WIN, and other Canadian herbaria.

Franklin, J. See Hooker, W. J.

Frankton, C. DAO

Fraser, W. P. SASK

Gaiser, L. O. Her own herbarium is at DAO; another significant repository is OAC; many early specimens are at HAM.

Gardner, G. His own herbarium is at SLU; early collections are at QFA; duplicates are widely distributed.

Garton, C. E. He was the founder and leading collector of specimens at LKHD; duplicates are widely distributed in Canadian herbaria.

Gaultier, J. F. P

Gauthier, R. QFA

Gibson, J. See Macoun, John.

Gillett, J. M. CAN, DAO; duplicates are in several other herbaria.

Given, D. R. Canadian specimens collected with C. E. Garton and J. H. Soper, q.v.

Godfrey, C. C. See Eames, E. H.

Goldie, J. See Hooker, W. J.

Goltz, J. P. Ontario specimens at TRT and in herbarium of R. E. Whiting, below.

Graham, A. BM

Gray, A. He received specimens from several resident collectors in Canada, as well as specimens of Canadian origin from W. J. and J. D. Hooker and other British botanists, and specimens collected by Moravian missionaries in Labrador through various agencies. Specimens collected by U.S. explorers in the Arctic, including A. W. Greely, were often also sent to Gray. His herbarium became the nucleus of GH.

Greely, A. W. See Gray, A.

Groh, H. DAO

Haenke, T. P. X. W

Hainault, R. His own herbarium is private; duplicates and other specimens are at DAO, QK, and several other Canadian herbaria.

Hallworth, B. M. UAC

Harms, V. L. SASK

Hart, H. C. Specimens from arctic Canada are at BM and K.

Haven, J. See Moravian missionaries.

Hay, G. U. His own herbarium is believed to have been destroyed in the Halifax fire of 1917; the principal repository of his extant specimens is NBM; others are at ACAD and elsewhere.

Hay, S. G. GMNP, MT

Hay, W. See Sloane, H.

Henn, C. B. See Moravian missionaries.

Henry, J. K. His own herbarium was destroyed; duplicates are at UBC, V, GH and elsewhere.

Herriot, W. His own herbarium is at OAC; specimens collected with Macoun in western Canada are at CAN; duplicates are widely distributed in Canadian herbaria.

Herzberg, J. G. See Moravian missionaries.

Hettasch, R. P. See Moravian missionaries.

Hincks, W. TRT

Hinds, H. R. UNB

Hitchcock, A. S. US

Holm, H. T. The principal repository of his own collections from Greenland, and specimens from arctic Canada sent to him, formerly at LCU, is CAN; C is another major repository of his own specimens; duplicates are widely distributed.

Holmes, A. F. MTMG

Hooker, J. D. Specimens studied by him, including those from several of the Arctic expeditions from 1850 through 1859, are at K. See also Arctic explorers 1818-1859.

Hooker, W. J. He studied specimens from several of the earlier British expeditions to the Arctic, as well as specimens from present-day Canada sent to him by many military officers, government officials, and amateur naturalists. He also studied the herbarium specimens from D. Douglas's expedition in western British North America. Hooker's herbarium became the nucleus of K. "See Hooker, W. J." in the present list refers to these individuals, many of whose names appear in Hooker's (1829-1840) *Flora Boreali-Americana*. See also Arctic explorers 1818-1859.

Hosie, R. C. CAN, TRT

How, H. NSPM

Hudson, J. H. SASK

Hultén, E. Principal repository S; duplicates are widely distributed.

Hustich, (V.) I. GB, H, MT

Hutchins, T. See Graham, A.

Jeffrey, J. E. duplicates are at CGE and K.

Johansen, F. See Anderson, Rudolph M., for specimens collected by the Canadian Arctic Expedition; other arctic specimens collected by him are at CAN and C.

Johnson, J. D. CAFB

Johnson, J. W. CAN, HAM

Johnson, K. L. MMMN

Jussieu, A. de P

Jussieu, B. de P

Kalm, P. LINN

Kendall, E. N. See Hooker, W. J.

Kennicott, R. Most of his specimens were destroyed in the Chicago fire of 1871; small numbers are at F, NY, and US.

Kindberg, N. C. Canadian bryophyte specimens sent by Macoun are at S.

King, R. See Hooker, W. J.

Kohlmeister, B. G. See Moravian missionaries and Lambert, A. B.

Krajina, V. J. Canadian specimens are at UBC.

Krivda, W. DAO; duplicates are widely distributed.

Kruth, F. See Moravian missionaries.

Kucyniak, J. MT

Kuijt, J. Principal repository for specimens from Waterton Lakes National Park WPH; LEA, MO, and UVIC are other significant repositories.

Lambert, A. B. Lambert's herbarium, which included many specimens collected by Moravian missionaries in Labrador, as well as other relatively early specimens from North America, was divided into numerous lots for sale after his death; see Miller (1970) for information on purchasers and present repositories. PH is especially significant for specimens collected by Kohlmeister that were formerly in Lambert's herbarium.

Lawson, G. His early Canadian collections, and the herbarium of the Botanical Association of Canada, are at QK; his own herbarium, formerly at Mount Allison University, is now at CAN (not retained at Mount Allison University as is sometimes stated; see Boivin 1980).

Ledingham, G. F. Principal repositories SASK, USAS; smaller numbers are at other, mostly Canadian, herbaria.

Lepage, E. The principal repositories for specimens from boreal Québec and Ontario, collected on the expeditions by Lepage, Dutilly, and Duman, was LCU, from which the Canadian specimens were transferred to CAN, except Cyperaceae to US (Tucker et al., 1989), and Lepage's own herbarium, formerly at RIM, now at QFA; duplicates are in many herbaria, especially DAO and MT. The primary repository for his other specimens is QFA.

Lide See Sloane, H.

Lindsay, A. W. H. NSPM

Lindström, A. H. See Amundsen, R.

Long, B. H. See Fernald, M. L.

Loring, C. G. See Agassiz, (J.) L. (R.).

Louis-Marie, Père His herbarium, formerly at l'Institut Agricole d'Oka, is now at QFA.

Low, A. P. CAN

Lowe, C. W. WIN

Lundberg, J. See Moravian missionaries.

Lyall, D. See Arctic explorers 1818-1859.

Lyon, G. F. See Arctic explorers 1818-1859.

McCalla, W. C. His own herbarium is at ALTA.

M'Clintock, F. L. See Arctic explorers 1818-1859.

M'Clure, R. J. LeM. See Arctic explorers 1818-1859.

Mackay, A. H. His own herbarium is believed to have been destroyed in the Halifax fire of 1917. The principal repository of his extant specimens is NSPM; specimens sent to Lawson are at CAN.

McKay-Kuja, S. M. TRT

Maclagan, P. W. See Hooker, W. J.; his specimens are also at CGE, E, and DUE.

McMorine, J. K. QK

McNab, J. His own herbarium is at DBN; other significant repositories of specimens from his 1834 expedition to North America are BM and E.

Macoun, James M. CAN

Macoun, John CAN; duplicates of his early collections are at QK; duplicates of his later collections are very widely distributed, C, DAO, F, GH, K, and NY being among the most significant repositories.

Macoun, W. T. See Macoun, John

Mactavish, W. CAN

Malaspina, A. See Haenke, T. P. X.

Malte, M. O. CAN; duplicates are widely distributed.

Marie-Victorin, Frère He was the founder and one of the principal contributors of specimens to MT; many duplicates are at GH, K, NY, P, SFS, and elsewhere.

Maycock, P. F. His own herbarium is private; duplicates and other specimens are at APM, DAO, MTMG, TRT, TRTE, and other Canadian herbaria.

Meidinger, D. SMI, V

Menzies, A. See Hooker, W. J.; many specimens are also at BM.

Metsger, D. A. TRT

Michaux, A. P

Miertsching, J. A. See Arctic explorers 1818-1859.

Millman, T. L. His own herbarium is at TRT; duplicates sent to Macoun are at CAN.

Mociño, J. M. MA

Montgomery, F. H. Principal repository OAC; smaller numbers are at DAO, TRT, and other Canadian herbaria.

Moore, M. I. Her own herbarium is private; duplicates and other specimens are at CAN, DAO.

Moravian missionaries. Specimens collected by Moravian missionaries in Labrador are very widely distributed. In Europe, sets of exsiccatae were assembled for sale, and the purchasers sometimes divided them further. In North America, GH and PH are the most significant repositories, with F, MO, WY, CAN and QFA being among those having smaller quantities. GH is particularly significant as a repository of specimens collected after 1890 as well as for earlier specimens. Kohlmeister material is found at PH. In Europe, BM, BR, C, DBN, E, FI, K, LE, M, P, UPS, and Z are among the more significant repositories. See Pringle (1992) and Cayouette and Darbyshire (1994) for further information.

Morisset, P. QFA

Morrison, R. See Hooker, W. J.

Morton, James A. His own herbarium is at UWO; MSC is another major repository; duplicates are widely distributed.

Morton, John K. WAT; duplicates are at CAN and several other herbaria.

Moss, E. H. ALTA, DAO, UAC

Moyen, J. Reported by Boivin (1980) to be at Collège de Montréal.

Mulligan, G. A. DAO

Nares, G. See Hart, H. C.

Nordenskjöld, (N.) O. (G.) The specimens from his Yukon expedition are at S.

Ogilvie, R. T. CAFB, UAC, V

Oldham, M. J. His own herbarium is private; duplicates are at CAN, DAO, and several other Canadian herbaria.

Packer, J. G. ALTA; DAO is another major repository.

Parry, W. E. See Arctic explorers 1818-1859.

Payette, S. QFA

Peary, R. E. The primary repository for specimens from the Peary polar expeditions is US; duplicates are at several other herbaria.

Pease, A. S. See Fernald, M. L.

Penny, W. See Arctic explorers 1818-1859.

Perceval, A. M. See Hooker, W. J.; duplicates are at DAO and DWC.

Petiver, J. See Sloane, H.

Polunin, N. V. BM OXF duplicates are widely distributed e.g. GH.

Porsild, A. E. Principal repository of Canadian specimens is CAN; many others are at MTMG, with duplicates widely distributed; principal repository of Greenland specimens is C.

Porsild, R. T. CAN
Provancher, L. QPH
Pursh, F. His specimens collected in Canada were mostly destroyed, some duplicates went to GH through the Sheppards. See also Lambert, A. B., whose herbarium included many specimens studied by Pursh. Pursh also studied specimens of Canadian origin in the herbaria of W. J. Hooker and other British botanists (see Ewan 1952 and Pringle 1992); these specimens are now at E and K.
Rae, J. See Arctic explorers 1818-1859.
Raup, H. M. Principal repositories of Canadian specimens A, GH, CAN; duplicates are widely distributed.
Raymond, M. His own herbarium, formerly at MTJB, is now housed at MT.
Reznicek, A. A. His own herbarium is private; duplicates and other specimens are at APM, CAN, MICH, TRT.
Richardson, James CAN, QK, MTMG
Richardson, John See Hooker, W. J.
Rigby, J. K. See Welsh, S. L.
Riley, J. L. TRT
Robb, J. UNB; specimens sent to W. J. Hooker are at K.
Roberts-Pichette, P. UNB
Robinson, B. L. GH
Robinson, C. B. Most of his Canadian specimens were destroyed; extant Canadian specimens are at GH and NY.
Roland, A. E. ACAD, NSAC; duplicates are widely distributed; many of his early specimens were destroyed.
Rolland-Germain, Frère. His own herbarium is at SFS; MT is another major repository; duplicates are widely distributed.
Ross, J. See Arctic explorers 1818-1859.
Rouleau, (J. A.) E. MT, NFLD; duplicates are widely distributed.
Rousseau, C. UQTR; QFA and DAO are other significant repositories.
Rousseau, (J. J. J.) J. MT, QFA; duplicates are widely distributed in Canadian herbaria; also at P.
Roy, J. D. Her own herbarium was probably discarded after her death (not at QK, as is sometimes stated, although specimens that she sent to Fowler are there); specimens exchanged with many private collectors are widely distributed (see Pringle 1989, for some of the repositories).
Roy, L. D. See Provancher, L.

Sabine, E. See Arctic explorers 1818-1859.
Saint-Cyr, D. N. QUE
St. John, H. Principal repositories of early specimens from the Gulf of St. Lawrence CAN and GH.
Sanson, N. B. UAC, NY
Sarrazin, M. P
Saunders, W. E. UWO
Schrenk, H. von GH
Schuchert, C. See Peary, R. E.
Schultz, J. C. CAN
Scoggan, H. J. CAN; DAO is another major repository.
Scott, P. J. NFLD
Scott, W. TRT
Scotter, G. W. Principal repositories of vascular plants CAFB, DAO; duplicates and non-vascular plants are at several other herbaria.
Scouler, J. Principal repositories of Canadian specimens BM, K; duplicates are in several, mostly British herbaria.
Senn, H. A. Early specimens, from Canada, are mostly at DAO. His later specimens are at WIS, but probably include few if any from Canada.
Shay, J. M. W. WIN, WINDM
Sheppard, H. C. See Hooker, W. J.
Sheppard, W. See Hooker, W. J.
Simmons, H. G. Principal repositories of Canadian specimens C, LD; other significant repositories include K, O, TROM, and, for bryophytes, H.
Simpson, T. See Dease, P. W.
Skelton, E. G., and E. W. TRT
Sloane, H. Specimens collected for Sloane, and also for Petiver, whose herbarium he acquired, are at BM.
Smart, J. See Sloane, H.
Smith, E. C. ACAD
Somers, J. NSPM
Soper, J. H. Principal repositories CAN, TRT; duplicates are widely distributed.
Spreadborough, W. See Macoun, James M., Macoun, John, and Low, A. P.
Stecker, A. G. See Moravian missionaries.
Stewart, W. G. DAO, UWO
Straley, G. B. UBC
Sutherland, D. A. Principal repository TRTE; duplicates are at CAN, DAO, and WAT.
Sutherland, P. C. See Arctic explorers 1818-1859.
Sverdrup, O. See Simmons, H. G.
Szczawinski, A. F. Principal repositories of vascular-plant specimens UBC, V

Talbot, S. S. Principal repository of vascular-plant specimens DAO; duplicates and non-vascular plants are at several other herbaria.
Tamsalu, A. HAM
Taverner, P. A. See Macoun, John.
Taylor, J. See Arctic explorers 1818-1859.
Taylor, R. L. Principal repositories of Canadian specimens DAO, UBC.
Taylor, T. M. C. CAN; early specimens, from eastern Canada, are also at TRT; later specimens, from British Columbia, are at UBC and V.
Tilden, R. See Sloane, H.
Todd, C. C. See Hooker, W. J.
Traill, C. P. Her own herbarium was destroyed; modest numbers of specimens are at CAN, QK, TRT, TUP and perhaps elsewhere.
Turner, G. H. His own herbarium is at ALTA; DAO is another major repository, and UAC for bryophytes; duplicates are widely distributed.
Tyrrell, J. B. CAN

Varga, S. TRTE
Venn, J. M. WAT; see also Morton, J. K.

Waghorne, A. C. His own herbarium was destroyed; duplicates are widely distributed (see references cited at the beginning of this appendix for repositories). Botanists to whom he sent specimens for identification are noted in the text.
Walker, D. See Arctic explorers 1818-1859.
Watt, D. A. P. His own herbarium is at MO; E is another major repository; duplicates are widely distributed.
Weatherby, C. A. See Fernald, M. L.
Webber, J. M. TRTE
Weiz, S. See Moravian missionaries.

Welsh, S. L. BRY, ISC, NY; ALTA and CAN are other major repositories.
White, C. D. See Peary, R. E.
White, J. His own herbarium is at TRT; his specimens contributed to the herbarium of the Entomological Society of Ontario are at OAC; duplicates are widely distributed in Canadian herbaria.
Whiting, R. E. His own herbarium is private, willed to TRT; principal repository of duplicates TRT; others are at CAN, DAO, MICH, OAC.
Wiegand, K. M. See Fernald, M. L.
Williams, M. M. BRY
Williams, R. S. His own herbarium is at F; principal repository for Canadian specimens is NY; duplicates are widely distributed.
Winter, J. See Hooker, W. J.

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The History of the Exploration of the Vascular Flora of Saint-Pierre et Miquelon

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Although early records were contributed by French explorers and naval officers, the floristic knowledge of Saint-Pierre et Miquelon largely represents the efforts of resident amateurs. The most notable were Ernest-Amédée Delamare, active 1850s-1880s; frère Louis-Arsène, on the islands 1895-1903; Mathurin Le Hors and père Casimir-Julien-Marie Le Gallo, active 1930s-1950s. In recent years, such studies have been continued by Roger Etcheberry and Daniel Abraham.

Key Words: Saint-Pierre et Miquelon, history, flora.

Although the French islands of Saint-Pierre et Miquelon are only about 20 km from the Burin Peninsula of Newfoundland (Figure 1) and only 242 square km in total land area, the history of their floristic exploration is significantly distinct from that of Canada. This history has been well recorded, reviews having been published by Louis-Arsène (1927), Le Gallo (1954), and Rouleau and Lamoureux (1992), along with biographical sketches of most of the participants.

The first botanical explorer on Saint-Pierre et Miquelon was Auguste-Jean-Marie Bachelot de la Pylaie (1786-1856; spelling of name varies), a French naturalist. On a brief visit to these islands in 1816 and a longer stay in 1819-1820, he collected specimens of vascular and non-vascular plants representing, according to Bonnet (1888), 215 species. These were later sent to the Muséum national d'Histoire naturelle in Paris via René-Louiche Desfontaines. Bachelot de la Pylaie intended to prepare an illustrated flora of Newfoundland and these islands, but its publication foundered after 1829, in part because of a lack of subscribers and in part because of its author's changing interests. It also appears that he was imprisoned for his political activities, at least briefly, during the 1830s. Only one fascicle of the flora, on marine algae, was ever published (Bachelot de la Pylaie 1830). Three lesser works that were published mentioned higher plants and animals that Bachelot de la Pylaie encountered on his voyages to Newfoundland, presumably including some that were found on Saint-Pierre et Miquelon, although these islands were not mentioned in the titles. Much more material, listed by Leroy (1957) and Catling et al. (1986), remains in Bachelot's manuscripts in the national archives of France and in the Muséum national d'Histoire naturelle in Paris. In his later years, Bachelot de la Pylaie concentrated on archaeology and mineralogy (Boyer 1948; Le Gallo 1948a, 1955a and references cited therein; Leroy 1957; South 1980).

In 1822 Charles-François Beautemps-Beaupré (1766-1854, on whom see Prevost 1949), a French naval officer and former ambassador to the United States, traveled to many parts of the world charting the coastlines and conducting other scientific studies. He collected specimens of 38 species on Saint-Pierre et Miquelon (Louis-Arsène 1927; Leroy 1957); these specimens are likewise at the Muséum national d'Histoire naturelle in Paris.

No significant botanical exploration of the islands followed until 1858, when Alphonse Gautier (1834-?, on whom see Le Gallo 1948a), a pharmacist, was sent from France to work at the hospital at Saint-Pierre, where he remained for five years. Gautier's observations on the natural history and meteorology of the islands were published and submitted as a doctoral thesis to l'Université de Montpellier in 1866. He listed 181 vascular plants, but, as noted by Louis-Arsène (1927) and Le Gallo (1948a), he provided no documentation, and later botanists have doubted some of his identifications. Some plants were identified only to genus, and some "difficult" groups, such as the Cyperaceae, were largely omitted from consideration. Many species collected by Bachelot de la Pylaie and Beautemps-Beaupré were not mentioned in his list.

The archipelago's first long-term resident botanical explorer was Ernest-Amédée Delamare (1835-1888, on whom see Le Gallo 1948a), a surgeon sent from France by the navy in 1858. After four years he was recalled to France for enhancement of his professional qualifications, and while he was there a disagreement led to the severance of his naval affiliation. In 1866, however, the colonial authorities invited him back as a civilian physician, and he spent the remaining 22 years of his life in practice in the village of Miquelon. It was during this time that he undertook his botanical studies, concentrating on Miquelon and doing little if any botanizing on Saint-Pierre. He corresponded with and sent specimens to

a number of European botanists, notably Ambroise Viaud-Grand-Marais of Nantes, France, through whom many of his specimens reached the Muséum national d'Histoire naturelle in Paris. He received medals from the international exposition at Paris in 1875 and the exposition at Anvers in 1885 for his studies of the peat bogs of Miquelon. Several taxa typified by Delamare's specimens were named for him, those accepted today being the marine brown-algal genus *Delamarea* Har. and the fresh-water moss *Fontinalis novae-angliae* Sull. var. *delamarei* (Renauld & Cardot) W. H. Welch.

In 1888 Edmond Bonnet, a Parisian botanist who did not himself visit the islands, published the first flora of Saint-Pierre et Miquelon, based on specimens collected by Bachelot de la Pylaie, Beautemps-Beaupré, and Delamare. Meanwhile Delamare himself collaborated with two French bryologists, Ferdinand Renauld and Jules Cardot (not themselves collectors on the islands), in writing a flora of Miquelon, which was published the same year. This flora listed 246 species, but, as noted by Louis-Arsène (1927), Delamare concentrated his attention largely on bryophytes and missed some of the more common vascular plants. The French botanists P. A. Hariot (1889) and F. C. G. Arnold (1887) published, respectively, on Delamare's specimens of algae and lichens.

The previous year abbé Jules Dominique (1838-1902) of Nantes, France, had published a short note on the flora and fauna of Miquelon (Dominique 1887), but neither Delamare and his French collaborators nor Louis-Arsène cited any vascular-plant specimens collected by him, although they presumably would have been aware of any such specimens had they existed. In France, at least, his botanical interests were concentrated on lichens.

Arthur Charles Waghorne (1851-1900), a Church of England clergyman, began publication of a list of the vascular plants of Newfoundland, including Labrador and the French islands, in 1893, following many years of field work. This list remained incomplete at the time of his death, treating only the polypetalous and gamopetalous dicots. Between parishes in Newfoundland, Waghorne had been his denomination's chaplain of Saint-Pierre et Miquelon in 1876-1877, and doubtless his own botanical collections included specimens from these islands. Much of his floristic list, however, was based on earlier publications, including that of Delamare et al. (1888) (Anonymous 1891; Brassard 1980).

The resurgence of interest in floristics in Québec around the turn of the century (Pringle: 1995:326) was paralleled on Saint-Pierre et Miquelon, beginning with the work of frère Louis-Arsène (né Jean-Marie Bizuel 1875-1959). Louis-Arsène came to Saint-Pierre from his native France as a teacher in 1895, and remained until his school was closed in 1903 and the Frères de l'Instruction Chrétienne were expelled from the islands. He subsequently served as a teacher and administrator in several schools in Québec and Ottawa. Eventually his administrative duties in the Frères de l'Instruction Chrétienne led to extensive travels to other parts of the world, and much of his later life was spent on the island of Jersey (Channel Islands, U.K.) and in nearby parts of France (Le Gallo 1962).

Louis-Arsène made 130 field trips on both main islands, although he felt that his exploration of Miquelon remained inadequate. Twenty-four years after his "sudden and final departure" from Saint-Pierre, he published a list of the vascular plants then known from the islands, augmented by 129 taxa through his own discoveries (Louis-Arsène 1927). This paper contained extensive discussions of soils, plant communities, and phytogeographic relationships; critical assessments of earlier reports; and the historical review noted above. Like Marie-Victorin and others in Québec, Louis-Arsène corresponded with M. L. Fernald at Harvard, who checked the identifications of many of his specimens. Other specimens of vascular plants were sent to N. L. Britton and J. K. Small at the New York Botanical Garden, including a mountain ash-chokeberry hybrid now called x*Sorbaronia arsenei* (Britton ex Louis-Arsène) G. N. Jones, named for its discoverer by Britton. Unlike his predecessors, Louis-Arsène gave particular attention to *Carex*. Many of his additions to the known flora were in this and other cyperaceous genera, but a remarkable number of species in other families, some conspicuous and distinctive, were also first reported by him.

On far-off Jersey, Louis-Arsène maintained his interest in the flora of Saint-Pierre et Miquelon and communicated with those who succeeded him in its study. The first of these was Mathurin Le Hors (1886-1952, on whom see Le Gallo 1955b), a native of the same department of France in which Louis-Arsène's order was based. At Saint-Pierre he was first a secondary-school teacher and administrator, later an electrical engineer for Cable-Français and Western Union. According to Louis-Arsène (1947), Le Hors "assiduously studied botanically not only the small Island of Saint-Pierre, but every corner of Great Miquelon and Langlade," beginning in the 1930s. He was joined in this exploration by père Casimir-Julien-Marie Le Gallo (b. 1906), at that time a priest in the town of Saint-Pierre. Many of their specimens were sent to Louis-Arsène, through whom they came to the attention of Fernald, who was acknowledged (Le Gallo 1954) for many identifications or verifications, along with H. K. Svenson of the New York Botanical Garden (for *Eleocharis*) and several botanists in Montréal. In 1947 Louis-Arsène listed the taxa — 124 native and 26 introduced — that Le Hors and Le Gallo had added to the known flora. Some of these were varieties and

MAP 1. Saint-Pierre et Miquelon (adapted from map in Louis-Arsène 1927:75).

forms, but representatives of five families of vascular plants and 30 genera hitherto unknown from the islands were among their discoveries. Their thoroughness also led to the rediscovery of several previously recorded taxa not found by Louis-Arsène, e.g., *Osmunda regalis* L., last reported by Gautier.

Le Gallo published several papers on the vascular plants, algae, and lichens of the islands, including an "esquisse générale de la flore vasculaire," a detailed exposition of the different habitats and plant communities (Le Gallo 1947). This was followed by a complete list of the known vascular flora, with a historical review and notes on distribution and taxonomic problems (Le Gallo 1954), as well as an extensively annotated list of the marine algae (Le Gallo 1948a). After moving to Lac-au-Saumon on Québec's Gaspé Peninsula about 1946, Le Gallo's botanical pursuits concentrated more on the marine algae, but he published some notes on Gaspesian vascular plants as well. He also botanized in the West Indies during the 1950s.

Le Gallo's (1954) list brought the total known vascular flora of the islands to 459 species, of which

94 were introduced, plus three interspecific hybrids. Other than those already mentioned in the present paper, only three individuals were cited as collectors of specimens, one in association with Le Gallo himself, and each of those for only one species.

Beginning in 1979, floristic exploration on the islands has been undertaken by Roger Etcheberry and Daniel Abraham, both residents of Saint-Pierre. They have discovered 13 additional native and numerous introduced flowering-plant species, and have also collected bryophytes (Etcheberry et al. 1987; Rouleau and Lamoureux 1992). In 1987, Etcheberry repatriated the herbaria of Louis-Arsène and Le Hors from France, thereby, in combination with his and Abraham's own contributions, providing Saint-Pierre et Miquelon with its first institutional herbarium, at the Archives de la Collectivité territoriale de Saint-Pierre et Miquelon.

Ernest Rouleau's list of the vascular plants of the Province of Newfoundland, of which the third edition was published in 1978, also listed the vascular plants of Saint-Pierre et Miquelon. Although Rouleau (1916-1991) botanized extensively on the island of Newfoundland, his coverage of the French islands was based on herbarium records and published reports. Rouleau's list was followed by an *Atlas* (Rouleau and Lamoureux 1992), which lists and in most cases provides distribution maps for the vascular-plant species of Saint-Pierre et Miquelon as well as the island of Newfoundland. These islands are included in the natural-history bibliography for Newfoundland and Labrador compiled by Laird (1980) and in the bibliography of vascular-plant floristics for insular Newfoundland compiled by Catling et al. (1986).

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Appendix: Principal Repositories of Herbarium Specimens from Saint-Pierre et Miquelon Collected by Persons Mentioned in this Paper

Standard references on the present repositories of herbarium specimens relevant to the present study include *Index Herbariorum, Part 2*, comprising *Regnum Vegetabile* 2, 9, 86, 93, 109, 114, and 117, and Boivin (1980). Additional information has graciously been supplied by Dr. Jacques Cayouette in personal communication. Abbreviations for herbaria follow Holmgren et al. (1990). Because most of those who botanized on Saint-Pierre and Miquelon prepared specimens of both vascular and non-vascular plants, the citations below indicate the repositories of all botanical specimens collected by these persons.

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Bachelot de la Pylaie, A. J. M. P, PC

Beautemps-Beaupré, C. F. P

Delamare, E. A. P, PC, L

Etcheberry, R. Archives de la Collectivité territoriale de Saint-Pierre et Miquelon.

Gautier, A. None known to be extant; might be sought at MPU.

Le Gallo, C. J. M. MT, QFA

Le Hors, M. Archives de la Collectivité territoriale de Saint-Pierre et Miquelon, DAO

Louis-Arsène, frère. Principal repository of specimens from Saint-Pierre et Miquelon is Archives de la Collectivité territoriale de Saint-Pierre et Miquelon; some duplicates are at GH and NY.

Waghorne, A. C. His own herbarium was destroyed; duplicates are widely distributed (see references cited at the beginning of this appendix for repositories); see also Pringle (1995: 321, 345).

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The History of the Exploration of the Vascular Flora of Greenland

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Lutheran and Moravian missionaries collected the earliest botanical specimens from Greenland. More intensive floristic studies began early in the nineteenth century, with Danish exploring expeditions that included well-qualified botanists, notably Morten Wormskjold and J. L. M. Vahl. Later in that century, many Danish, Swedish, British, German, and American expeditions brought botanists to Greenland. After 1906, scholars based at the Disko Arctic Station, especially M. P. Porsild, contributed much to floristic knowledge. Botanists on Danish, Norwegian, and other expeditions during the first half of the twentieth century included Eugenius Warming, H. G. Simmons, and P. F. Scholander. From the 1930s to the present, botanists from the university and botanical garden at Copenhagen have conducted much research in Greenland, among them T. J. Sørensen (founder of the Greenland Botanical Survey), T. W. Böcher, Richard Bøgvad, and K. A. Holmen.

Key Words: Greenland, history, flora.

For all its remoteness, Kalâllit-Nûnat — traditionally known as Greenland and thus referred to in this paper — has been well explored botanically. As well as amateurs, professional botanists with doctorates from Rostock and Copenhagen visited this land remarkably early, and by the end of the nineteenth century scientific expeditions were almost continuously present in Greenland. Consequently, even some of the early botanical collectors cannot feasibly be mentioned here. Greenland's botanical history, however, has been well recorded, nearly every floristic work having included a review of previous botanical study and collecting in the area covered. The early history of botanizing in Greenland was reviewed by Brown in 1868. A brief summary of the floristic exploration of Greenland was published by Jørgensen et al. in 1958, and a more thorough summary of floristic work between 1939 and 1949 was compiled by Böcher (in Noe-Nygaard et al. 1951). A detailed history for the much-botanized vicinity of Disko Island on the west coast through 1918 was published by Porsild and Porsild (1920) and updated to 1962 by Böcher (1963). Seidenfaden (1933) listed 110 localities on the southeast coast at which plants had been collected, with the names of collectors from 1829 through 1932; another detailed review for southeastern Greenland, listing numerous collectors by localities, was compiled by Devold and Scholander (1933); and yet another such list with the names of several more recent collectors was published by Böcher (1938). The early botanical exploration of northwestern Greenland north of Melville Bay was reviewed by Simmons (1909); a later history of floristic exploration in the Melville Bay area, from 73° to 77°48′, was compiled by Sørensen (1943). Gelting (1934) reviewed the botanical exploration of northeastern Greenland through 1933. More recently, Feilberg (1984) summarized the floristic exploration of both the east and west coasts south of 62°20′, noting several significant floristic investigations during the 1970s and early 1980s. Also, Bay (1993a) summarized the floristic exploration of Greenland north of 74°, listing many geologists and amateur naturalists who contributed to floristic knowledge during the 1970s through the early 1990s and mapping the sites of botanical collecting, as well as reviewing the more intensive botanical research in the area. Additional papers on the botanical exploration of Greenland have been cited in the bibliographies compiled by Warming (1881), Adams and Norwell (1936), Blake and Atwood (1942), and Kleppa (1973). Localities of major significance in the history of floristic exploration are shown in Map 1.

Early Botanizing by Missionaries and Explorers

The earliest botanical specimens from Greenland were collected by Hans Poulsen Egede (1686-1758, called "the father of modern Greenland" by M. L. Fernald) and his son Poul Egede (1708-1789), Norwegian missionaries sent to Greenland by the Danish Lutheran Church. They arrived in 1728 and established a mission at Godthåb (now Nûk), where the senior Egede served until his retirement in 1736. Poul Egede served at Christianshåb until 1758, when he went to Copenhagen to become an administrator and later to devote full time to translations and linguistic studies (Anonymous 1926; Lagerkranz 1950: 17-18; Gad 1973). The Egedes' albums of specimens still exist in the Botanical Museum at Copenhagen. Missionaries of the Moravian Church (Unitas Fratrum) were also early

MAP 1. Greenland, showing major sites of botanical exploration noted in the text.

contributors of botanical specimens. As early as 1767-1768 the missionary Christoph Brasen (1738-1774) collected plants in the vicinity of Godthåb. Even earlier another Moravian, David Crantz (1723-1777), had included extensive notes on the flora and vegetation in his *History of Greenland* (title of translation), published in 1765. Another early botanical collector among the Moravian missionaries was Johan Michael Eberle (1773-1859), who was in Greenland from 1804 to 1839. Especially notable as an early botanical collector was J. F. D. Tietzen (1794-1858), who served at Ny Herrnhut, near Godthåb, from 1824 to 1835, then at nearby Lichtenfels (on the west coast, near Fiskenæsset, at 63°4′N) until his death (botanical specimens dated 1851-1855) (Porsild 1935). Others appropriate to mention here were Immanuel Schneider (1822-1885), in Greenland from 1851 to 1875, who contributed specimens from Umånaq (on Godthåb Fjord, at 64°30′N); and members of the Kögel family, of whom Heinrich August Kögel (1834-1918, in Greenland from 1867 to 1896) was the most interested in botany, although his father Johannes (1793-1873) and/or uncle Caspar (1801-1862, in Greenland from 1829 to 1862) collected botanical specimens at Lichtenau (on the west coast, at 60°30′N) during the 1850s and early 1860s (Porsild, 1935, 1946; J. Cayouette, personal communication in 1993). A few other early Moravian missionaries who collected plant specimens in Greenland were mentioned by Brown (1868) and Porsild (1946). Studies by Jacques Cayouette in progress at the time of this writing have indicated that specimens from Greenland collected by Moravian missionaries in the early 1850s typify some of the plant names published in E. G. von Steudel's *Synopsis Plantarum Glumacearum*.

The first major investigator of the Greenland flora, and the first to have had a university education in botany, was Morten Wormskjold (1783-1845), who had studied under J. W. Hornemann in Copenhagen. Wormskjold, at the time a naval lieutenant, led an expedition to Greenland in 1813, on which he obtained botanical specimens in the Godthåb and Julianehåb districts and areas in between, and recorded observations on the plant communities (Warming 1890).

Charles Lewis Giesecke (né Karl Ludwig Metzle, 1761-1833), a native of Germany, lived in Greenland from 1806 through 1813, conducting scientific studies for the Danish government. He devoted his attention primarily to mineralogy but also collected botanical and other specimens along Greenland's west coast (Devold and Scholander 1933). Upon leaving Greenland he was appointed Professor of Mineralogy to the Royal Dublin Society, and the remainder of his life was spent in Ireland (Praeger 1949; Sarjeant 1980).

Wilhelm August Graah's expedition by umiak in 1829-1830 included among its members Jens Lorenz Moestue Vahl (1796-1854, on whom see Stafleu and Cowan 1986), a botanist subsequently affiliated with the Botanical Museum at Copenhagen. In 1829 Vahl obtained specimens at 15 localities on Greenland's southeast coast, north to ca. 61°48′. Graah (1793-1863) continued north to 68°20′ after Vahl had turned south and collected plants at additional localities (Devold and Scholander 1933). The following year Vahl explored the southwest coast. Vahl, characterized by Porsild and Porsild (1920) as an "able and thoroughly scientifically trained botanist," spent most of the next six years in Greenland on behalf of the Danish government, and obtained large numbers of plants in the vicinity of Godhavn on Disko Island and at other localities on the west coast north to Upernavik.

Royal Navy expeditions from the United Kingdom also contributed significantly to the knowledge of the Greenland flora during the nineteenth century. The first of note in this context was Douglas C. Clavering's expedition to Greenland and Svalbard in 1823, which mapped the east coast of Greenland between 72°5′ and 75°12′, and on which the astronomer-naturalist Edward Sabine (1788-1883) obtained botanical specimens from Pendulum Island, ca. 74°45′, and other localities on that coast. Other naval expeditions of particular significance botanically were those of William Penny in 1850-1851, on which plants were collected by Peter Cormack Sutherland (1822-1900); and Edward Belcher in 1852-1854, on which plants were collected by David Lyall (1817-1895). The west coast as far north as Disko Island was the principal source of Greenland plants on these and other expeditions en route to the Canadian Arctic Archipelago. On Francis Leopold M'Clintock's expedition of 1857-1859, the surgeon, David Walker (1837-1917), botanized at several localities from Frederikshåb to Upernavik. The expedition in 1852 commanded by Edward Augustus Inglefield (1820-1894), on leave from the Royal Navy on behalf of Lady Franklin, is of note for specimens obtained by its leader at Wolstonholme Sound, 76°30′, and on the shores of the gulf that now bears his name. (On the plant collectors mentioned here see Desmond 1994, and references cited therein; on Walker see also Anonymous 1917a; on the expeditions and leaders see, *inter alia*, Berton 1988; on the botanical work of these expeditions in the Canadian Arctic, see Pringle 1995: 296, and references cited therein.)

The first and most important of the non-Navy British explorers who collected plants in Greenland was William Scoresby (1790-1857, on whom see Desmond 1994 and references cited therein, also Berton 1988), a whaling captain by vocation, a sci-

entist by inclination. From 1808 through 1822 he explored the coasts of Greenland and, among other activities, collected botanical specimens as suggested by his friend Sir Joseph Banks. On his last and most scientifically oriented expedition he charted ca. 650 km of the east coast, sailed as far north as the great fjord or sound that now bears his name, ca. 70°, and brought back plant specimens from poorly botanized eastern Greenland. Other British plant collectors in Greenland during the nineteenth century included James Taylor (1823-1913), a surgeon on whaling vessels, and Robert Brown (b. Campster; 1842-1895), a member of the expedition led by Edward Whymper in 1867, both of whom botanized on Disko Island and several other sites on the west coast between Egedesminde (68°42′) and Kudlesnæt (70°5′) (Brown 1868; Porsild and Porsild 1920; Desmond 1994). The expeditions led by Elisha Kent Kane (1820-1857), an American, especially his Second Grinnell Expedition in 1853-1855 (on which see Berton 1988), obtained specimens from several localities on Greenland's west coast, extending floristic knowledge north to the shores of Smith Sound. As did other arctic expeditions of the time, this expedition encountered great hardships, in this case losing some of its members to disease, after which the survivors abandoned the ships, which had become trapped in the ice, and travelled 2100 km in small boats and on foot to Upernavik. It is amazing to present-day students that any scientific specimens were preserved.

Later Nineteenth-Century Expeditions: Exploration intensifies

The Second German North Polar Expedition (zweite deutsche Nordpolarfahrt) of 1869-1870 included a voyage by the steamer *Germania* up the east coast of Greenland from 66°20′ to 75°30′, with particular attention being given to the exploration of Franz Joseph Fjord at 73°15′, and also to Scoresbysund (Venzke, 1990 and references cited therein). The numerous vascular-plant specimens, collected primarily by Adolf Pansch (1841-1887), were studied and listed by F. G. P. Buchenau and W. O. Focke (1873) of Bremen (not themselves collectors in Greenland), and the non-vascular plants were reported upon by other botanists (Stafleu and Cowan 1976).

In 1870, a Swedish expedition led by (Nils) Adolf Erik Nordenskjöld (now noted for many subsequent expeditions and exploits in the arctic regions, especially his exploration of the north coast of Siberia) proceeded inland ca. 50 km, starting from Auleitsivikfjord, on the west coast ca. 100 km south of Jakobshavn. Nordenskjöld was accompanied by Sven Berggren (1837-1917, on whom see Anonymous 1917b), professor of botany at Lund. Berggren collected botanical specimens at various localities en route, including several sites in the vicinities of Godhavn and Jakobshavn, the Nûgssuaq Peninsula and the Egedesminde District, and the islets offshore (Porsild and Porsild 1920), and published on the plant ecology of the middle west coast. Later he botanized in Australia, New Zealand, and the United States.

The Swedish Arctic Expedition of 1871 included Thore (a.k.a. Theodor) Magnus Fries (1832-1913), a botanist who had studied under J. P. Arrhenius at Uppsala (thereby being an "academic grandson" of his own father, the renowned mycologist E. M. Fries) (Hemmendorff, 1914). Fries, a veteran of previous arctic voyages, obtained numerous plant specimens on the west coast, especially from Disko Island.

The British Polar Expedition of 1875-1876, commanded by George S. Nares and noted for its floristic accomplishments in Arctic Canada (Pringle 1995: 302), also visited Greenland, spending a week at Disko Island. The naturalist was Henry Chichester Hart (1847-1908), whose "rich collections of plants" included many range extensions in Greenland (Porsild and Porsild 1920; Desmond 1994).

Ludwig Aaron Kumlein (1853-1902, on whom see Anonymous 1903), naturalist on the American expedition to Baffin Island organized (but not participated in) by Henry W. Howgate, spent three weeks on Disko Island in 1878, and obtained a quantity of botanical specimens. The vascular plants were identified and listed by Asa Gray (1879), the fungi by W. G. Farlow, and the lichens by Edward Tuckerman.

The indefatigable Baron Nordenskjöld was again exploring Greenland in 1883, this time along the west coast. On this expedition the botanical collecting was done by Johan August Berlin (1851-1910, on whom see Anonymous 1910) and Alfréd Gabriel Nathorst (1850-1921, on whom see Seward 1921a,b and Halle 1921), in the vicinities of Godhavn and the Vajgat [north] Coast of Disko Island (Porsild and Porsild 1920). Nathorst, a noted Swedish geologist and paleobotanist, later led expeditions of his own to northeastern Greenland, primarily in search of fossil plants. The most significant to studies of the modern flora was that of 1899, on which the Swedish botanist Per Karl Hjalmar Dusén (1855-1926, on whom see Birger 1926), also known for his botanical explorations of South America, obtained numerous specimens from the east coast between 70° and 75° (Dusén 1901).

The east coast, hitherto much less well explored botanically, was the destination of Gustav Holm's expedition in 1883-1885. The botanist in the southern party, Peter Johan Alexej Conradt

Eberlin (1862-1900), collected plants at 30 localities between Kap Farvel (Cape Farewell), Greenland's southernmost point, and Umanak, ca. 62°54′. Several other Danish expeditions of this period have been noted by Porsild and Porsild (1920) and by Devold and Scholander (1933). Collections by these and other expeditions, and in smaller quantities by Danish officials and their families and by missionaries, formed the basis of *Conspectus Florae Groenlandicae* (Lange 1880-1892), "the first scientific flora of Greenland," compiled by Johan Martin Christian Lange of the polytechnic university at Copenhagen (not himself an explorer of Greenland) in 1880-1881, with supplements in 1887 and 1889-1894 (the latter by J. L. A. K. Rosenvinge et al.), in which 371 species were listed (Porsild and Porsild 1920; Böcher et al. 1968).

Late Nineteenth and Early Twentieth Centuries: Exploration becomes more scientifically oriented

Johannes Eugenius Bülow Warming (1841-1924, on whom see Rosenvinge et al. 1924, Smith 1924, and numerous references cited by Stafleu and Cowan 1988), one of the most renowned figures in plant ecology, first came to Greenland as a member of the Danish government expedition on the *Fylla* in 1884. His assistant, with the responsibility of preparing plant specimens, was Herman Theodor Holm (1854-1932), who had been his student at the University of Copenhagen, and who later became known for his studies of the arctic and Rocky Mountain vegetation of North America (Woods 1933). Warming and Holm studied the vegetation around most of the major west-coast ports and some other localities between Frederikshåb and Godhavn (Warming 1886). Their floristic discoveries were reported in Rosenvinge's supplement to Lange's *Conspectus* (above). Warming subsequently studied the flora of many parts of the world and published on systematic and developmental botany, but he is best known for his pioneering research in ecology. His studies in Greenland led to a major treatise on its vegetation (Warming 1888), one of many works that were forerunners of his *magnum opus* on plant communities and adaptation, *Plantesamfund* (also published in a much-expanded English edition as *Oecology of Plants*).

Nikolai Eeg Kruse Hartz (1867-1937), at the time a geology instructor at the Statens Lærerhøjskole in Copenhagen, began his botanical studies of the west coast of Greenland in the summers of 1889 and 1890. During the next two years he was a member of C. H. Ryder's expedition to Scoresbysund, and in 1900 he participated in G. C. Amdrup's expedition (below) to Christian IX Land and other sites on the east coast. His observations and numerous botanical specimens became the basis of several major treatises on the arctic vegetation. Like Nathorst, he became especially interested in Greenland's fossil flora; it was in Quaternary paleobotany that he took his doctorate at Randers in 1909 and became best known later in his career (Jessen 1937).

An expedition was sent out by the Gesellschaft für Erdkunde zu Berlin [Germany] in 1891-1892 under Erich von Drygalski, with the primary objective of studying ice formations along Greenland's west coast, and went as far north as 80°. The expedition naturalist, Ernst Vanhöffen (1858-1918, on whom see Stafleu and Cowan 1986), professor of zoology at Kiel, obtained botanical specimens at several localities.

As botanist on an unspecified but presumably Danish governmental expedition in 1897, Christian Kruuse (1867-1952) went to Disko and the Egedesminde District in 1897. At several localities on the mainland and on nearby islands he studied the flora and took numerous measurements of temperature and wind for ecological studies (Kruuse 1898). He returned to Greenland in 1898-1899 and again in 1900 as a member of two expeditions to the east coast led by G. C. Amdrup. (On Amdrup's own botanical contributions see Devold and Scholander 1933.) Kruuse had been given extensive instructions on plant collecting by his mentor, Eugenius Warming, but he returned frustrated by having had too little time for botanical study and by much of that having been at Scoresbysund, already explored by Scoresby, the Second German North Polar Expedition, the Ryder Expedition, and others. His best results on the first voyage had been at Søndre Bræfjord, where he had had "only 105 minutes" ashore, and at Sabine Island on the second voyage, on which he was accompanied by Hartz. Therefore he organized his own expedition, supported — as Amdrup's expeditions had been and as much Danish science and exploration henceforth would be — by the Carlsberg Foundation. In 1901-1902 he collected thousands of botanical specimens in the Angmagssalik District on the east coast from 65°35′ to 75° (Kruuse 1904, 1905, 1906; Hartz and Kruuse 1911). Kruuse himself listed the vascular plants then known from 64 localities in east-central Greenland, his own explorations having produced many range extensions, and other botanists treated his discoveries among the non-vascular plants (*Meddelelser om Grønland* 30 *passim*).

Porsild Era Begins: Disko Arctic Station established, many expeditions from several nations

Morten Pedersen Porsild (1872-1956, on whom see Gröntved 1956), who was to become one of the most important figures in Greenland's botanical history, first came to Disko Island in 1898 as a member of K. J. V. Steenstrup's expedition. Four years later the Danish government again sent Porsild to western Greenland to study the vegetation, especially that of northern Disko Island. In 1906 his efforts toward the establishment of the Danish Arctic Station (on which see Ekblaw 1918b) on Disko Island came to fruition, and he became its first director. During the 40 years that he held this post he botanized extensively on the island and at other localities from 66° to 71° on the west coast, adding a number of species to the known flora of Greenland and eventually compiling a list of the plants of Disko Island and vicinity with copious ecological notes (Porsild and Porsild 1920). Although botany was his primary interest, he also published on zoology, geology, meteorology, and ethnology. His later botanical work was shared with his two older sons, Robert Thorbjørn Porsild (1898-1977) and Alf Erling Porsild (1901-1977, on whom see Soper and Cody 1978), who subsequently became Chief Botanist at the National Museum of Canada. Morten P. and A. Erling Porsild also journeyed south in 1924, botanizing at many localities, notably including Julianehåb and Prins Christian Sund, between Godhavn and Nunatsuk, the latter locality being on the southeast coast (Porsild 1930).

The flora of far-northern Greenland (i.e., north of ca. 78°30′), hitherto represented by few specimens other than the small collections made there by Inglefield, Kane, and Vanhöffen, began to be studied in earnest in 1898-1902. The scientifically outstanding Second Norwegian Arctic Expedition in the *Fram*, commanded by Otto Sverdrup, included as botanist Herman Georg Simmons (1866-1943, on whom see Dahlgren 1944), a Swedish scholar subsequently on the faculty of the agricultural college at Ultuna. He collected and listed many plants found at Foulke Fjord near Etah at 78°18′ and at a few points farther south on the west coast (Simmons 1904, 1909). There followed the *Danmark* expedition (a Danish expedition; orthography from the name of its ship), also of major scientific significance, in 1906-1908, led until his death by L. Mylius-Erichsen (on this expedition see, *inter alia*, *Meddelelser om Grønland* 27 *in toto*). Its botanist was Andreas Lundager (1869-1940), who had already botanized around Egedesminde, where he had worked as a tutor (Lindhard 1940). He obtained specimens at 26 localities from Koldewey Island, off the east coast at 76°30′, to Frederick E. Hyde Fjord, Peary Land, 83°15′, the majority of the localities being in Germania Land (Ostenfeld and Lundager 1910).

Robert E. Peary's expeditions were scientifically limited by the primacy of the polar quest, but support parties nevertheless contributed to floristics. The most significant of Peary's expeditions to Greenland floristics was that of 1892, with William Edward Meehan (1853-1930) as botanist. He collected plant specimens at numerous localities between Godthåb and Littleton Island, the latter ca. 78°, including Inglefield Gulf, McCormick Bay, Godhavn, and Upernavik (Meehan 1893). Botanical specimens were obtained at several localities on the west coast of Greenland between 70° and 74°10′, as well as from the east coast of Baffin Island in Canada, by Cornell University geologist Ralph Stockman Tarr (1864-1912) and entomology student James Otis Martin (1870-1951), accompanying the Peary expedition of 1896 (Rowlee and Wiegand 1897); and by the geologists (Charles) David White (1862-1935), of the United States Geological Survey, and Charles Schuchert (1858-1942), at that time an amateur, later at Yale University, and others in 1897 (Holm 1900). On the expedition of 1908-1909, specimens were collected at Etah and vicinity on Smith Sound, chiefly by Robert Abram Bartlett (1875-1946), captain of Peary's ship *Roosevelt*. (See Meehan 1893; Rowlee and Wiegand 1897; Holm 1900; Simmons 1913; Rydberg 1911-1912; Porsild and Porsild 1920; Ewan and Ewan 1981; and Crowder et al. 1993 for botanical and biographical information and names of other collectors; Berton 1988 *inter alia* on the expeditions.)

The expedition led by Louis Robert Philippe, Duc d'Orléans, in 1905, was notable primarily for its accomplishments in oceanography. It did not go quite so far north, but expedition member Carl Andreas Koefoed (1855-1948) contributed to the floristic knowledge of Duc d'Orléans Land and Dove Bay on the northeast coast (Ostenfeld 1907; Ostenfeld and Lundager 1910).

A great deal was added to the scientific knowledge of far-northern Greenland by the Thule Expeditions led by Knud Rasmussen, a Danish explorer and ethnologist. The first, in 1912, afforded relatively little opportunity for floristic study, but expedition member Peter Freuchen (1886-1957, on whom see his autobiography, 1953) collected some plants in Melville Land on the north shore of Independence Fjord, at several localities around the head of the fjord, and at Danmark Fjord, all in northeastern Greenland, and around Thule on the west coast (Ostenfeld 1915). On the second Thule Expedition in 1917 (on which see Freuchen 1953) the Swedish botanist Thorild Wulff (1877-1917, on whom see Anonymous 1918; Ekblaw 1918a; and Ostenfeld 1923c) perished on the icecap. Earlier on this expedition, however, Wulff had made numerous botanical collections and ecological observations at 16 localities southwest of Peary Land, from Midgaardsormer, 81°15′, to Low Point, 83°6′

(Ostenfeld 1923c). Rasmussen also established a trading and research station at Thule on North Star Bay, on the north shore of Wolstonholme Sound. Several scientists based there who collected botanical specimens during this period, as well as some missionaries of the Danish Lutheran church in the area who likewise contributed, have been listed by Ostenfeld (1923a). The vascular plants from these and other researches in northern Greenland at that time were studied and listed by Carl Emil Hansen Ostenfeld (1923a,b,c) of Copenhagen, who also collaborated with M. Oskar Malte in studies of the Canadian arctic flora. The bryophytes were studied by Christian August Hesselbo.

In 1914-1916 the Crocker Land expedition (named for the land reported by Peary that this expedition proved did not exist), led by the American explorer Donald Baxter MacMillan, visited northwestern Greenland (Ekblaw 1919). Its geologist and botanist was Walter Elmer Ekblaw (1882-1949, on whom see Schorger 1952), later of the geography faculty at Clark University, Worcester, Massachusetts. In 1914 and 1916 Ekblaw spent the summers at the mission at North Star Bay; in 1915 he botanized along the coast from Hall Basin south to Etah. He brought back "thousands of beautifully prepared specimens," the first set of which was later given to the Gray Herbarium of Harvard University and published upon by M. L. Fernald (1934).

The next botanically important voyage to Greenland's far north was the Danish Bicentenary Jubilee Expedition in 1920-1922, led by Lauge Koch (1892-1964, on whom see Müller 1964), a geologist, who collected some of the plant specimens himself. Most of the botanical work was done by Jeppe Noe-Nygaard, who made "very rich collections" in Washington Land and Inglefeld Land, respectively the northeast and southeast shores of Kane Basin, and on the shores of Murchison Sound (Ostenfeld 1925).

Albert Charles Seward (1863-1941, on whom see Thomas 1941), a paleobotanist at Cambridge University in England, visited western Greenland in 1921 primarily to collect specimens of its rich fossil flora (Cretaceous through Pleistocene). Seward's assistant was Richard Eric Holttum (1895-1990), who obtained numerous specimens of the modern flora as well (Seward 1925). At Godhavn this party was joined by A. E. Porsild, who prepared the floristic notes (Porsild 1926). Shortly thereafter, Holttum became assistant director (later director) of the Botanic Gardens, Singapore, and began his long and productive career in pteridology and other branches of systematic botany (Holttum 1975; Jermy 1990).

The Danish East Greenland Expedition of 1929 was primarily geological, but it included the botanist Gunnar Seidenfaden (b. 1908, on whom see Stafleu and Cowan 1985), who collected plants between 72°42′ and 74°33′ (Seidenfaden 1929). Seidenfaden later authored additional papers on the Greenland flora and also on Canadian arctic phytoplankton.

The next major contributions to Greenland floristics were made by six Norwegian expeditions. The first of these, sent out by the Norwegian government's Svalbard-og Ishavs-undersøkelser in 1929 and led by A. K. Orvin, included as its botanists Bernt Arne Lynge (1884-1942) from Oslo University, who concentrated on lichens, and Jakob Vaage, who collected all plant groups and prepared the report on the vascular plants (Vaage 1932). This work resumed the following year, with Per Frederik Scholander (1905-1980, on whom see Stafleu and Cowan 1985) having replaced Lynge. Large numbers of specimens were obtained from Eirik Raude's Land, on the east coast from 71°30′ to 75°40′.

The next four Norwegian expeditions went to the southeast coast. The first of these, in 1931, was also sent out by the Svalbard-og Ishavs-undersøkelser; it was led by Thorolf Vogt, with Bjørn Bjørlykke (1909-1938, on whom see Holmboe 1938) as botanist. Vogt and Bjørlykke obtained a large quantity of botanical specimens from several regions between 62°20′ and 64°30′ (Bjørlykke 1932). Two other expeditions were organized and sponsored by Peter S. Brandal, Sr., a Norwegian patron of science and exploration. The first of these, in 1931, was led by Johannes Kristoffer Tornøe, who also collected botanical specimens, and visited several localities from ca. 60°20′ north to the vicinity of Scoresbysund (Lid 1932). Greater numbers of specimens were obtained by an expedition in 1932, co-sponsored by the University of Oslo and led by Peter S. Brandal, Jr. The Svalbard-og Ishavs-undersøkelser sent Scholander and Joakim Devold (b. 1908) on this expedition. These two botanists worked together at many localities north to ca. 63°40′, after which Scholander continued with the expedition north to Scoresbysund, while Devold transferred to a Svalbard-og Ishavs-undersøkelser expedition that visited a number of additional localities along the southeast coast. Devold and Scholander's (1933) account of the known flora of southeastern Greenland listed 107 localities from Kap Farvel to the Kangerdlugsuak District, ca. 68°30′, at which plants had been collected by 14 individuals up to that time. Additional botanical papers on Norwegian expeditions to Greenland dur-

Morten Pedersen Porsild, 1937
(courtesy of the Hunt Institute for Botanical Documentation,
Carnegie-Mellon University).

The Sørensen Era: Many floristic and ecological studies

Another of the most important figures in Greenland's botanical history was Thorvald Julius Sørensen (1902-1973), one of Ostenfeld's students. Sørensen fell in love with Greenland as a member of the Danish Three-Year Expedition of 1931-1934, led by Lauge Koch, and spent the rest of his career studying its plant life. His most significant floristic explorations were made during this expedition, in northeastern Greenland from 71° to 79°. The results were written up in collaboration with Gunnar Seidenfaden, with whom he had shared some of the field work (Sørensen 1933; Seidenfaden and Sørensen 1937). Sørensen's research on Greenlandic botany was remarkably diverse: he published a classic work on solifluction and arctic soil structure based on observations in northeastern Greenland; described plant communities there, and discussed adaptations of Greenland plants to their harsh environment; authored taxonomic revisions of *Puccinellia* and *Potentilla* complexes; determined the chromosome numbers of many Greenland plants; and investigated apomixis in *Ranunculus* and *Taraxacum*. In Denmark, Sørensen was employed by the Botanical Museum in Copenhagen from 1935 to 1943, taught systematic botany at the Landbohøjskolen from 1943 to 1955, then returned to the Botanical Museum as director of the museum and botanical garden (Jørgensen et al. 1958; Jakobsen 1974; Stafleu and Cowan 1985; and references cited therein).

Another party in the Three-Year Expedition, working just to the south of Sørensen and Seidenfaden, included as botanist Paul Gelting (1905-1964, on whom see Hansen 1964), who studied the flora between Franz Joseph Fjord and Dove Bay (Gelting 1934). Gelting's (1934) report named several other members of the expedition who collected plants, and noted three other expeditions to Greenland in 1931 that also contributed to floristic knowledge.

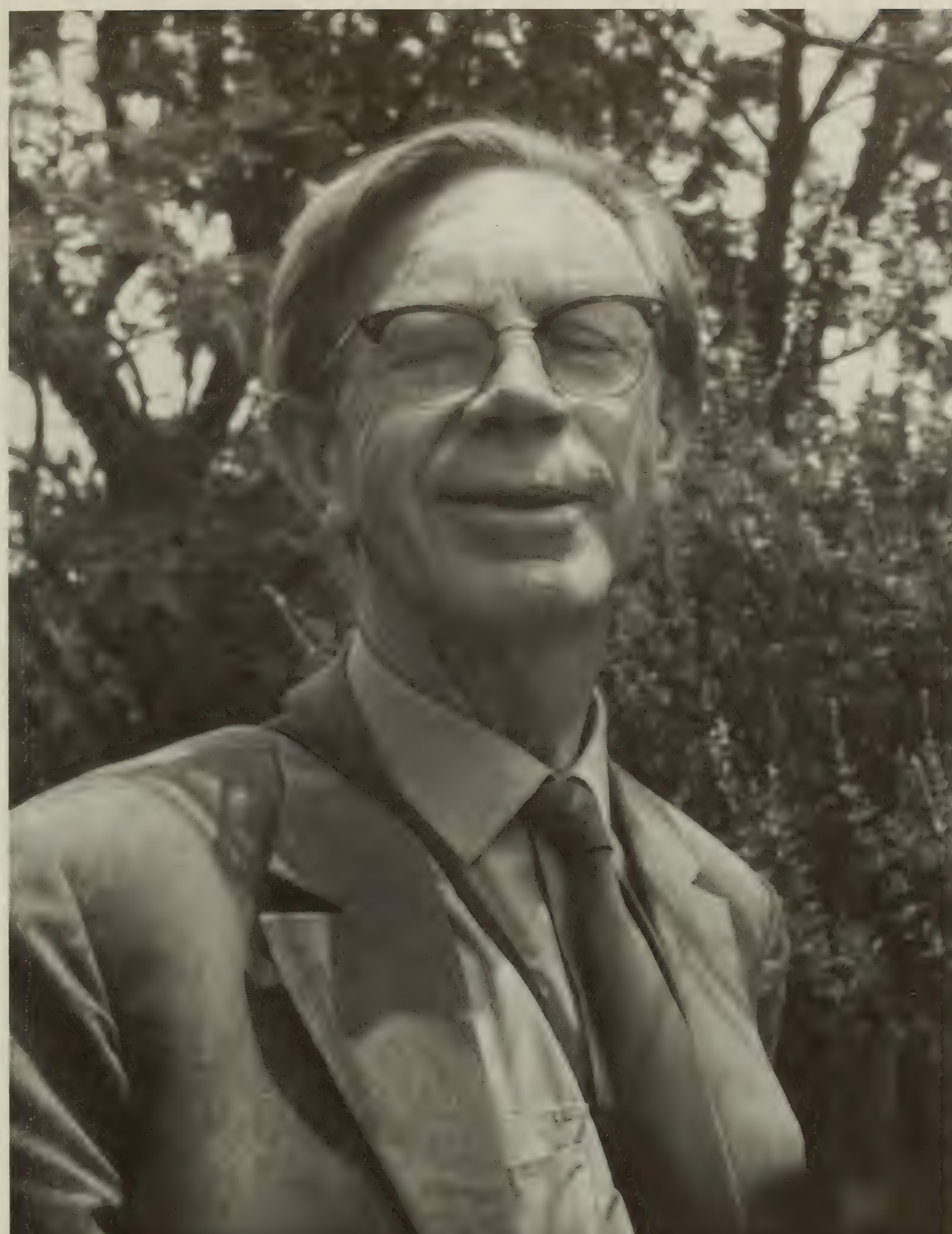
The Scoresby Sound Committee, a private Danish organization established to assist the Greenland natives, later expanded its role to include science, and in 1932 launched its Second East Greenland Expedition with Tyge Wittrock Böcher (1909-1983) as botanist. Böcher, at that time a graduate student at the University of Copenhagen, thus began the research that led to his becoming an authority on Greenland floristics and phytogeography. He also became a pioneering researcher in plant biosystematics, and served as director of the Institute of Plant Anatomy and Cytology at his alma mater (Löve 1984). On this expedition numerous specimens were obtained in the hitherto poorly botanized region — where Kruuse had been frustrated by the little time available for botanical study — between Angmagssalik, at 65°37′, and Scoresbysund (Böcher 1933). Böcher published not only a floristic paper but also an extensive treatise on the ecology of this area, and other botanists listed his discoveries of non-vascular plants (*Meddelelser om Grønland* 104 *passim*).

Meanwhile, Rasmussen's Thule Expeditions continued. The sixth and seventh explored the east coast from Kap Farvel to Scoresbysund. Most of the plant collecting was done by (Sidney) Richard (Emil) Bøgvad (1897-1952, on whom see Troelsen 1953), a geologist, who "contrived to make an astonishing number of new finds" at many localities. The botanical results of these expeditions were initially written up by Seidenfaden (1933). Later, Böcher (1938) made extensive use of Bøgvad's botanical discoveries in a major treatise on the phytogeography of southern and eastern Greenland. By that time it was possible for Böcher to supplement his discussions with numerous maps illustrating distribution patterns among Greenland plant species. The botanical contributions of later Thule expeditions have been noted by Böcher (in Noe-Nygaard et al. 1951).

Especially large numbers of plants were collected in Greenland during the 1930s by John Ludwig Lagerkranz (1875-1954), a Swedish clergyman and amateur botanist supported in this work by grants from the Royal Academy of Sciences in Stockholm. In 1934 he went to many localities on the west coast from Ivigtut, at 61°13′, to Upernavik, 72°47′, giving particular attention to Disko Island, the Nûgssuaq Peninsula, and the vicinities of Christianshåb and Jakobshavn. In 1936 he explored several of the fjords in the Godthåb (Nûk) District. In 1938 he botanized farther south, at Ivigtut and several of the peninsulas and fjords in that area. In 1946 he returned briefly to Ivigtut, then spent a relatively long time at Julianehåb. That same year he visited several localities on the east coast, including mountains and islands in the vicinity of Angmagssalik, and continued as far north as Scoresbysund. He published a detailed account of these trips, with descriptions of the vegetation at each locality as well as lists of plants (Lagerkranz 1950).

The Natural History Expedition to Northwest Greenland in 1936, led by Finn Salomonsen (b. 1909), was primarily zoological in its objectives, but large numbers of botanical specimens were also collected by Salomonsen, mostly between 73° and Kap York at 77°48′ on the west coast. The botanical discoveries of this expedition were written up by Sørensen (1943).

A few other botanical explorers of the 1930s should be mentioned here. Frits Johansen (1882-1957), an invertebrate zoologist who had been on the *Danmark* expedition and who later worked in Canada, organized his own expedition to Greenland in 1931 (Spärck 1957). His main objective was the



Thorvald Julius Sørensen, 1963
(photograph by Richard A. Howard; courtesy of the Hunt Institute for Botanical Documentation, Carnegie-Mellon University).

study of small crustaceans, but he also brought back many plant specimens from western Greenland. From 1924 through 1938, seven expeditions to the Arctic were organized and financed by Louise Arner Boyd (1887-1972) of San Francisco, California. The most significant to Greenland floristics was her 1937 expedition, on which the botanist was Henry John Oosting (1903-1968, on whom see Bliss 1969), a noted plant ecologist from Duke University. Oosting botanized at 24 sites along the fjords between 72° and 75° on the east coast, and published (Oosting 1948) extensive discussions of the plant communities along with a substantial species list. Miss Boyd's own most significant botanical collecting was done in 1938 at various localities on the east coast north to Ile de France (Eastwood 1948).

Post-World War II Developments

After World War II biological expeditions to Greenland, mostly from Denmark, were numerous. Indeed, one of Thorvald Sørensen's major accomplishments as director of the Botanical Museum was the arrangement of financial support for the Greenland Botanical Survey, with annual expeditions to Greenland. Only those expeditions that were especially significant in relation to publications and/or visited poorly botanized regions are noted below.

The Carlsberg Foundation supported further botanical exploration of Greenland by Tyge W. Böcher and his associates in 1946, 1958, and 1961. The most significant of these expeditions was the second, on which specimens were obtained at 31 localities on the west coast between 65°30′ and 70°. (On these expeditions, and for names of other members who collected plants, see Böcher 1963.) Böcher also made special note of the plants collected by Knud Jakobsen (b. 1924) of the Geological Survey of Greenland at many localities on the west coast north of 70°, between the Nûgssuak Peninsula and Orliks Fjord.

Kjeld Axel Holmen (1921-1974, on whom see Christiansen 1975 and Steere 1975), one of Böcher's colleagues and formerly his student at Copenhagen, was botanist on the Danish Peary Land Expedition. From 1947 to 1950 he spent four summers and one winter at Jørgen Brønlands Fjord (extending northwest from Independence Fjord) (Holmen 1952), and obtained "very extensive and valuable collections of plants" (Jørgensen et al. 1958) between Victoria Fjord on the west coast and Danmark Fjord on the east. His lengthy species list (Holmen 1957) cited 96 localities, some further divided and several named for plants, from which botanical specimens, many his own, were known. Many of these localities were in the eastern part of Peary Land, which hitherto had remained poorly botanized, and many were along interior waterways, Peary Land being largely unglaciated. This paper names other expedition members who made botanical contributions and summarizes earlier botanical exploration in the area. The changing aspect of botanical research in Greenland is evident from Holmen's (1952) cytological studies; he obtained chromosome counts for 74% of the vascular-plant species known for Peary Land.

In the summers of 1956, 1957, 1958, and 1960, while professor of botany at Harvard University, Hugh Miller Raup (b. 1901, on whom see Stafleu and Cowan 1983) studied the flora of the Meisters Veg area on the south shore of Kong Oscars Fjord, northeastern Greenland, and carried out ecological analyses of 57 sites (Raup 1965). Raup's paper on the flora noted plants collected in the same area by Finnur Gudmundsson and Hálfdán Björnsson of the Museum of Natural History, Reykjavik, Iceland, in 1955.

Rudolf Mathias Schuster (b. 1921) of the University of Massachusetts at Amherst visited Greenland on four occasions. In 1960 he botanized in the Thule area; in 1966 in the vicinities of Egedesminde and the Søndre Strømfjord airbase and on Disko Island and the Nûgssuaq Peninsula; in 1970 again on Disko and nearby shores; and in 1980 at Kap Farvel and other southern sites, on some of these occasions with Kell Damsholt (b. 1938), of the University of Copenhagen (Damsholt 1988). Although primarily interested in liverworts, on which he published annotated lists of the species known from southern and western Greenland north to 72° (Schuster and Damsholt 1974; Schuster 1988), he also collected vascular plants.

The national park established in 1976, comprising the east coast between 72° and 83°, and the adjacent east coast south to 70°, have been the subject of a floristic survey by both Danish and British botanists, who have made annual visits to this region for several years (Simpson 1989). British botanists also made significant contributions to Greenland floristics on the British North-East Greenland Expeditions of 1980 and 1990, organized by the University of Lancaster, with Geoffrey Halliday (b. 1933) heading the botanical studies (Bay 1993a).

Other recent programs that have contributed especially significantly to floristic knowledge include the studies in northern Greenland by Lars Stemmerik, of the Greenland Geological Survey, and T. Hauge Andersson, of the Danish Polar Center. Their research was primarily geological, but they also collected large quantities of botanical specimens (Bay 1993a).

Such projects, and the Greenland Botanical Survey mentioned earlier, are among the developments that have made it unfeasible to recognize in

this paper much of the botanical research conducted in Greenland in recent years. Also, with the flora now having been studied in so much of Greenland, field botany there has become less floristically oriented and more often focused on community and physiological ecology. An example is presented by the work of J. G. de Molenaar and F. J. A. Daniëls of the Botanical Museum at Utrecht, The Netherlands, in the Angmagssalik District in 1966, 1968, and 1969; although including floristic contributions (Daniëls and de Molenaar 1970), it has concentrated primarily on the classification and description of plant communities (de Molenaar 1974-1976, and other papers in this series by de Molenaar and Daniëls). Recognition should, however, be given to the list of the vascular plants of Greenland south of 62°20′ compiled by Jon Feilberg (1984) of the Botanical Museum, Copenhagen, a leading floristic investigator in the Greenland Botanical Survey. This paper includes extensive discussions of plant-distribution patterns and factors affecting distribution, as well as numerous maps. The second paper in this series, by Christian Bay (1993a), covers Greenland north of 74°. Bay is likewise notable for his many collections of botanical specimens from many localities in northern Greenland. A comparable study of the west coast from 62°20′ to 74°, by Bent Fredskild (b. 1929), is in preparation at the time of this writing. Bay and Fredskild accomplished much of their botanical exploration during the Greenland Home Rule Authority's biological-archeological project of 1988-1990, between 75° and 79°30′ (Bay 1993a).

The naturalized and other introduced plants of Greenland were the subject of a special study by Anfred Pedersen (1972), of the University of Copenhagen, whose own field work was conducted on the west coast north to Disko Island and on the extreme southeast coast. This report succeeded an earlier paper on the introduced flora by M. P. Porsild (1932).

Excellent manuals for the identification of the vascular plants of all of Greenland have been available since 1957, when the first edition of *Grønlands Flora*, by Tyge W. Böcher, Kjeld Holmen, and Knud Jakobsen, all of the University of Copenhagen, was published. Two years later Greenland was covered by *Circumpolar Arctic Flora* (Polunin 1959), a descriptive flora by Nicholas Vladimir Polunin (b. 1909), a British botanist whose extensive arctic travels had extended to Greenland in the 1930s. A revised edition of *Grønlands Flora* appeared in 1966, and a third edition in 1978, with Bent Fredskild, who had previously published on floristic studies near Jakobshavn and in Peary Land, as well as on Greenland paleobotany, as one of the authors. An English translation of the second edition was published as *The Flora of Greenland* (Böcher et al. 1968) in 1968. Although compact, this manual includes keys, descriptions, taxonomic and ecological notes, chromosome counts, distributional data, and numerous illustrations. By 1966 the number of taxonomically accepted plant species known to occur in Greenland had risen to 496; by 1993 this had increased to 513, the additions comprising more native species than introduced weedy species (Bay 1993b).

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Appendix: Principal Repositories of Herbarium Specimens of Greenlandic Origin Collected by Persons Mentioned in this Paper

Standard references on the repositories of herbarium specimens relevant to the present study include *Index Herbariorum, Part 2*, comprising *Regnum Vegetabile* 2, 9, 86, 93, 109, 114, and 117; Holmgren et al. (1990); and Desmond (1994). The incomplete list presented here can be supplemented by consulting those references and the biographical works on the individual collectors. Abbreviations for herbaria follow Holmgren et al. (1990).

Amdrup, G. C. C; see also Hartz, N. E. K., and Kruuse, C.
Andersson, T. H. C
Bartlett, R. A. Principal repository for specimens collected on Peary expeditions US; others at NY.
Bay, C. C
Belcher, E. Greenland specimens at K; see also Lyall, D.
Berggren, S. Principal repositories C, GB; duplicates are at several other herbaria.
Berlin, J. A. GB
Bjørlykke, B. O
Böcher, T. W. C
Bøgvad, S. R. E. C
Boyd, L. A. CAS, GH; see also Oosting, H. J.

Brandal, P. S., Jr. See Devold, J., and Scholander, P. F.
Brasen, C. None known to be extant.
Brown, R. (Campster) Greenland specimens at K.

Clavering, D. C. See Sabine, E.

Damsholt, K. C; see also Schuster, R. M.
Daniëls, F. J. A. U
Devold, J. O
Drygalski, E. von See Vanhöffen, E.
Dusén, P. K. H. Principal repository for Greenland specimens S; C is another major repository; duplicates are at several other herbaria.

Eberle, J. M. C
Eberlin, P. J. A. C. C, KIEL, L
Egede, H. C
Egede, P. C
Ekblaw, W. E. C, GH, K, MO, S

Feilberg, J. C
Finnur Gudmundsson ICEL
Fredskild, B. C
Freuchen, P. C
Fries, T. M. C, GB, K, LZ, S, UPS, W

Gelting, P. C
Giesecke, C. L. C
Graah, W. A. C; see also Vahl, J. L. M.

Hálfdán Björnsson ICEL
Halliday, G. LANC
Hart, H. C. BM, K
Hartz, N. E. K. Principal repository C; sets of exsiccatae in several herbaria.
Holm, G. See Eberlin, P. J. A. C.
Holm, H. T. The principal repository of his own collections from Greenland and those sent to him, formerly at LCU, is CAN, except Cyperaceae at US; C is another major repository; duplicates are widely distributed.
Holmen, K. A. C
Holttum, R. E. Greenland specimens at CGE.

Inglefield, E. A. K

Jakobsen, K. C
Johansen, F. Principal repository of Greenland specimens C.

Kane, E. K. C
Koch, L. C; see also Noe-Nygaard, J., and Sørensen, T. J.
Koefoed, C. A. C
Kögel, C. For all members of this family, the principal repository of botanical specimens is FI.
Kögel, H. A. See above.
Kögel, J. See above.
Kruuse, C. C
Kumlein, L. A. GH

Lagerkranz, J. L. C, S; duplicates are in several other herbaria.
Louis Robert Philippe = Orléans, duc d'; see Koefoed, C. A.
Lundager, A. C, S
Lyall, D. K
Lynge, B.A. O; duplicates are at several other herbaria.

M'Clintock, F. L. See Walker, D.
MacMillan, D. B. See Ekblaw, W. E.
Martin, J. O. BH
Meehan, W. E. MSC, PH; bryophytes also at NY
Molenaar, J. G. de U
Mylius-Erichsen, L. See Lundager, A.

Nares, G. S. See Hart, H.C.
Nathorst, A. G. C, S; duplicates are at several other herbaria.
Noe-Nygaard, J. C
Nordenskjöld, N. A. E. Principal repository of Greenland specimens K; duplicates are at several other herbaria; H, S-PA are major repositories of non-vascular specimens.

Oosting, H. J. CAS, DUKE
Orléans, duc d' See Koefoed, C. A.
Orvin, A.K. See Lynge, B. A., and Vaage, J.

Pansch, A. L (formerly B)
Peary, R. E. The principal collectors of botanical specimens from Greenland on expeditions commanded or organized by Peary were Bartlett, R. A., Martin, J. O., Meehan, W. E., Schuchert, C., Tarr, R. S., White, C. D., qq.v.
Pedersen, A. C
Penny, W. See Sutherland, P. C.
Polunin, N. V. Principal repositories of Greenland specimens BM, OXF; duplicates are in several other herbaria.
Porsild, A. E. C, CAN; duplicates are widely distributed.
Porsild, M. P. C; NY is another major repository.
Porsild, R. T. Greenland specimens at C

Rasmussen, K. C
Raup, H. M. A, CAN
Ryder, C. H. C; duplicates are at several other herbaria; see also Hartz, N. E. K.

Sabine, E. BM
Salomonsen, F. C
Schneider, I. C
Scholander, P. F. O; duplicates are widely distributed.
Schuchert, C. US
Schuster, R. M. C, DUKE, F; specimens mostly bryophytes.
Scoresby, W. BM
Seidenfaden, G. C, NY, S
Seward, A. C. CGE
Simmons, H. G. C, LD
Sørensen, T. J. C; duplicates are at several other herbaria.
Stemmerik, L. C
Sutherland, P.C. BM, K
Sverdrup, O. See Simmons, H. G.

Tarr, R. S. BH
Taylor, J. BM, K
Tietzen, J. F. D. C
Tornøe, J. K. C, O

Vaage, J. C, GB, O
Vahl, J. L. M. C; duplicates are widely distributed.
Vanhöffen, E. C (formerly B)
Vogt, T. See Bjørlykke, B.

Walker, D. BEL, K
Warming, J. E. B. Principal repository of Greenland specimens C; duplicates are at several other herbaria.
White, C. D. US
Whymper, E. BM
Wormskjold, M. C; duplicates are at several other herbaria.
Wulff, T. C, LD, S

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Combined Index to Personal Names

Compiled by JAMES S. PRINGLE

This is an index to the names of explorers and plant collectors, their collaborators and mentors, those who studied their plant collections, owners of historically significant herbaria, and authors of floras. These personal names are not indexed when used merely in the citation of publications, or when cited as the authors of botanical names. Except for those of a few individuals noted as having compiled major historical accounts, the names of persons cited only as authors of historical, biographical, or bibliographical references are not included in this index.

In this index as well as in the literature citations, names beginning with Mac, Mc, and M' are all indexed as though spelled Mac-, and those usually written St.- are indexed under Saint. Early French names that included the prefix de have been listed under the original surname when the prefix indicated an honour conferred upon the individual, but under D when the prefix was an integral part of the surname. Otherwise, in indexing names including de or von, I have followed such standard references as Stafleu and Cowan (1967-1988) and the respective authors' own practices in citing their papers. The names of Icelandic individuals (excluding emigrants who adopted surnames) are indexed according to the given name.

News and Comment

Contributions to the History of Botanical Investigations in Northern North America

The three featured articles in this issue of *The Canadian Field-Naturalist* are copublished with the Missouri Botanical Garden which had originally solicited them to be part of the introductory material for *The Flora of North America*. However, when completed, the manuscripts were too lengthy and comprehensive for inclusion, but too valuable as a reference to be abridged. Consequently, a Canadian partner was sought to co-publish them separately. The Publications Committee of The Ottawa Field-Naturalist's Club was approached and immediately endorsed their consideration for an issue of *The Canadian Field-Naturalist*. Subsequent peer review and confirmation by Ottawa Field-Naturalists' Club Council led to acceptance after minor revisions by the author.

The Canadian Field-Naturalist has a long tradition of publishing historical and tribute contributions and is particularly pleased by this opportunity to add to it through these papers. Background on the Missouri Botanical Garden is provided below followed by an autobiographical sketch of author James Pringle prepared at our request.

FRANCIS R. COOK
Editor

Missouri Botanical Garden

Over 250 000 kinds of plants (not counting algae or fungi) inhabit the Earth. Much of our basic verifiable knowledge, the description and relationships (taxonomy and systematics) that have contributed to, and continue to expand, our understanding of plant diversity, distribution, evolution, and importance as a fundamental part of the biosphere, is based on reference collections gathered and maintained in herbaria around the world. Comparisons made possible by such collections continue to result in the discovery and accurate definition of several thousand new species of plants every year on a world basis, and a continually improving classification of them.

Occupying a 79-acre site in St. Louis, the Missouri Botanical Garden has become a world leader in botanical research with partnerships with institutions in over 30 countries. It operates the world's most active tropical botany research program, has 30 000 members and an annual visitor attendance of over 800 000. Its herbarium is one of the largest in the United States. It was founded by Henry Shaw, an Englishman who arrived at the river town of St. Louis in 1819, where he prospered initially in the hardware business, later expanding to investments in agricultural commodities, mining, real estate, and furs. Success allowed him to retire by 1839, not yet 40, and by 1850 he resolved to spend the remainder of his life in acts of philanthropy, which came to include support to develop many St. Louis cultural and social institutions. Shortly after 1851, his strong interest in botany and gardening, fostered by the early school years he had spent on the estate of English botanist Peter Collinson, led him to begin development of a ten-acre site near his country home. Dr. George Engelmann, a St. Louis physician and one of the foremost United States botanists of the 19th century, subsequently convinced Shaw that the garden should be more than a public park and must also become involved with scientific work like the great botanical institutions of Europe and therefore include a herbarium. Shaw commissioned Engelmann to purchase a 62 000 specimen herbarium collection from the estate of German botanist Johann Bernhardi, assembled during the late 18th and early 19th centuries, and containing many interesting and important historical specimens from South America, Asia, and Africa, as well as from Europe. In 1858 the first acquisitions for a botanical library were made and in 1859 the Missouri Botanical Garden was opened to the public. In 1890, George Engelmann's private herbarium of about 100 000 specimens was donated by his family. This aquisition included major collections from many of the exploring expeditions to western North America and northern Mexico during the middle of the 19th century.

From this beginning, the Garden has built an expanding research program and an herbarium collection that, as of 31 December 1994, contained over 4.4 million mounted accessioned specimens (4 225 255 vascular plants and 262 773 bryophytes), including nearly 1.3 million from North America, 1.8 million from tropical America, 600 000 from Africa and 500 000 from Asia and Oceania. Some 190 000 specimens were added to the collection in 1994 alone through the exploration and collecting activities of Garden botanists and of collaborating institutions. The library contains more than 116 000 volumes, including more than 5000 rare books. In addition it has extensive non-book collections,

including Garden records and publications, professional and personal papers of Garden botanists, historic manuscripts, Garden photographs, oral histories, and architectural drawings.

Presently included in a Garden staff of over 300 are 54 Ph.D.-level research scientists and 95 technical and support personnel. Nearly 80 volunteers also participate in research programs. In 1994, 24 students from the United States and nine foreign countries were enroled in the Garden's graduate program in systematic botany in cooperation with Washington University, Saint Louis University, University of Missouri-St. Louis, and southern Illinois University at Edwardsville. Dr. Peter H. Raven, Director of the Garden, is Engelmann Professor of Botany at Washington University, and many of the curators are adjunct faculty members at one or more of the participating universities. Two students received doctoral degrees and two others received master's degrees, in 1993-1994.

In addition to the many gift specimens sent to specialists, the Garden's herbarium annually makes loans totalling 40 000 specimens to researchers throughout the world, borrows about 24 000 specimens for its own staff, and exchanges material with over 400 herbaria world-wide. The Garden is host to over 500 research visitors a year who utilize the herbarium and library collections.

The Research Division of the Garden produces a variety of ongoing publications: three serials — the *Annals of the Missouri Botanical Garden* (in its 81st year of publication in 1994), *Novon* (in its fourth year of publication in 1994), and *Monographs in Systematic Botany from the Missouri Botanical Garden* (volumes 47-52 were published in 1994); an assortment of botanical books, and various newsletters, including *Herbarium News* (volume 14 in 1994), *Flora of North America Newsletter*, *Flora of China Newsletter*, and *Plant Conservation*.

The Missouri Botanical Garden serves as the organizational centre for *The Flora of North America* project. This collaborative, binational effort involves more than 35 major botanical institutions to compile the first comprehensive description of all plants growing spontaneously in the United States, Canada, and Greenland. Fourteen volumes will be published over 12 years by the Oxford University Press and will contain names, descriptions, geographic ranges, maps and illustrations. More than 17 000 species of vascular plants alone occur north of Mexico. Thirty-eight percent of the genera native to this area are found only in North America and an additional 18 percent are found only in North, Central and South America. This project draws on botanists throughout the world, both as specialists to write individual treatments and as reviewers. The total cost of *The Flora of North America* is approximately $1 million U.S. per year, and it has received major funding from the National Science Foundation, the Pew Charitable Trusts, the David and Lucille Packard Foundation, the Surdina Foundation, the Dula Foundation, the ARCO Foundation, the Chase Garvey Foundation, the Hewlett Foundation, and the National Fish and Wildlife Foundation. It continues to seek funds.

Other major projects in which the Missouri Botanical Garden is participating are:

Flora Mesoamerica, the first major regional flora ever written in Spanish, a collaborative effort with the National Autonomous University of Mexico and the Natural History Museum in London, England. Seven volumes, scheduled for publication between 1993 and 2000, will cover an estimated 18 000 plant species occurring in the southernmost states of Mexico (including the Yucatan Peninsula) and all Central American republics.

The *Flora of China* project, a joint Sino-American effort to revise, condense and translate into English the massive Chinese-language *Florae Republicae Popularis Sinicae*, a catalogue of plants grown in China begun in 1959. The project will produce 25 volumes over the next 15 years on the approximately 30 000 species of plants, over 5000 of which are used as medicines in China. The coordination center for the project is at the Missouri Botanical Garden and editorial centres at the Smithsonian Institution, California Academy of Sciences, Harvard University, and the Royal Botanic Gardens, Edinburgh.

A botanical database, *TROPICOS*, first developed by Garden botanist Robert Magill in the early 1980s, has now been converted to a high-memory IBM RISC 6000 which runs on an AIX operating system and allows researchers to communicate easily with other systems on the Internet System. The RISC system provides the Garden access to the huge resources of mainframe computers at other institutions while still being able to work directly with colleagues using small personal computers. Data from the *Flora of North America, Flora Mesoamerica*, and *Flora of China*, as well as other smaller floristic projects throughout the world, are stored on *TROPICOS*, which is being constantly updated and now includes some 700 000 of the million published plant names and contains information on more than 170 000 type specimens, more than 650 000 distribution records, nearly 315 000 synonyms, and nearly 950 000 specimen records.

Other initiatives include a Natural Products Research Program that is dedicated to searching for plants with interesting chemical compounds that may be a source of chemicals that can be useful to humans as drugs, pesticides, herbicides or in other ways. While the Garden in not equipped to perform chemical screening and identification process, it is uniquely qualified to provide plant samples from

many areas of the world and can aid with the design of programs and analysis of data. In 1986, the Garden entered into a five-year contract with the National Cancer Institute to search for new drugs to combat cancer, and in 1991 a second five-year contract was signed. Working with other botanical institutions, Garden researchers collect plants in tropical Africa and Madagascar. In addition, the Garden works with the Monsanto Company's natural product screening program. In 1988, field workers began collecting 500 soil samples a year from tropical regions looking for novel soil microorganisms that might lead to new antibiotics; in 1990 two more Monsanto programs, both for plant materials, were added.

The Center for Plant Conservation, founded in 1984, the only national organization in the United States dedicated exclusively to preventing the extinction of native plants, is headquartered at the Missouri Botanical Garden. It consists of a network of 25 botanical gardens and arboreta nationwide that collect and maintain endangered plants in the National Collection of Endangered Plants which now contains more than 450 species.

In addition to the research initiatives the Missouri Botanical Gardens includes a complex of displays and associated public educational programs that include an Azalea/Rhododendron Garden, Gladney Rose Garden, Linnean House (built in 1882, the oldest continuously operated display greenhouse in the United States and featuring Camellias blooming throughout the winter months), Swift Family Garden, Bakewell Court Garden, Cohen Court Garden, Isabelle Baer Garden, Samuels Bulb Garden and Heckman Garden, Scented Garden, Hosta Walk, Goodman Iris Garden, Jenkins Daylily Garden, Milles Sculpture Garden, Climatron geodesic domed greenhouse (the symbolic image of the Missouri Botanical Garden, covering more than a half-acre), the Shoenberg Temperate House, Heckman Rock Garden and Dwarf Conifer Garden, Hardy Succulent Garden, Desert House, The Knolls, Dry Stream Garden, Mausoleum Grounds (the final resting place for Henry Shaw), Herb Garden, Kaeser Memorial Maze, Anne L. Lehmann Rose Garden, English Woodland Garden, Japanese Garden, and the Centre for Home Gardening. An extension of the Missouri Botanical Garden is the Shaw Arboretum, located 35 miles southwest of St. Louis, which includes 2500 acres of natural Ozark landscape and managed plant collections. The Shaw Arboretum was founded in 1925 when coal smoke from the city threatened the living plant collections housed at the Garden. The orchid collection was moved to this site in 1926, but pollution cleared in the city before it was necessary to move the entire plant collection.

FRANCIS R. COOK
Editor

Editor's Note: This text has been taken directly from a wide array of press releases and background papers provided by the Missouri Botanical Garden. Drs. Marshall R. Crosby and Nancy Morin corrected and updated (to 1994) an earlier draft. Further details on any of these programs or displays is available from the Missouri Botanical Garden, Public Relations Office, P.O. Box 299, St. Louis, Missouri, USA 63166.

James S. Pringle: Author's Autobiographical Note

The following autobiographical information, oriented toward my authorship of the papers in the present issue, is provided at the request of the editorial board of *The Canadian Field-Naturalist*.

I was born 14 August 1937 in Danvers, Massachusetts, U.S.A., but, because my family moved to Laconia, New Hampshire, in February 1941, I think of the latter as my home town. I attended the public schools in Laconia, and graduated in the Laconia High School class of 1954. No members of my immediate family had made a career in the biological sciences, but my mother and our next-door neighbour had gardens that developed as much or more as plant collections than as landscaping. Also, at that time, when the city was smaller, there were extensive woodlands and old fields within walking distance of my home, so I had many opportunities to develop an acquaintance with the local flora. Laconia High School was keenly competitive in interscholastic academic programs including science fairs, and my science teachers were highly supportive.

I received my bachelor's degree from Dartmouth College, in Hanover, New Hampshire, where all of the members of the Department of Botany, especially Drs. Carl L. Wilson and James P. Poole, further encouraged by interest in the plant sciences. My master's degree was awarded by the University of New Hampshire at Durham, where I began my studies of *Syringa* that have continued to the present, with Dr. Owen M. Rogers as my major professor. My doctorate in botany is from the University of Tennessee at Knoxville, where my faculty advisor was Dr. Aaron J. Sharp. Dr. Sharp also taught at the University of Michigan Biological Station, near Pellston, Michigan, and encouraged his graduate students to do part of their course work there. Of all my time at universities, I most enjoyed my summers at

U.M.B.S., where I developed a special interest in the flora of the Great Lakes region and specifically its disjunct and endemic species. After receiving my doctorate in 1963, I came to the Royal Botanical Gardens as plant taxonomist, which position I have held to the present.

Among my fellow plant taxonomists I am doubtless best known for studies of the Gentianaceae, which began with a taxonomic revision of *Gentiana* sect. *Pneumonanthe* in eastern North America as my doctoral dissertation. In recent years, I have written all or major parts of the treatments of the Gentianaceae for the floras of California and Ecuador, and that of *Gentiana* for *Flora Meso-Americana*. Among the taxonomic studies that preceded or were included in these floristic projects were revisions of, and descriptions of new species in, Mexican and Central American *Gentiana* and Ecuadorean *Gentianella*, *Halenia*, and *Macrocarpaea*. I have also published a number of new species descriptions and taxonomic notes on *Gentianella* in other South American countries. Projects on the Gentianaceae as of this writing include the treatment of the family for the *Flora of North America North of Mexico* and for the floras of Colombia and Trinidad and Tobago, as well as a taxonomic revision of *Gentiana* in Perú.

I have also written much of the treatment of *Clematis* for the *Flora of North America*, previously having published taxonomic studies of subgenus *Atragene*, including its taxa occurring naturally in North America and its representatives in cultivation. Other contributions to the *Flora of North America*, in progress at the time of this writing, include the treatments of *Gypsophila*, *Suriana*, and *Syringa*.

In systematics related to horticulture, I have published research and interpretive papers on the systematics of *Syringa*, a natural consequence of having written my master's thesis on lilacs and now being at the site of the world's largest lilac collection. At the interface of horticulture and natural history, I am interested in naturalized species in the Ontario flora, having reported new records of weedy species and escapes from cultivation. Some of the latter discoveries were made while exploring depopulated village sites for plants for the Royal Botanical Gardens' heritage garden.

Since beginning my teaching career with summer courses in general biology and general botany at Norwich University in Northfield, Vermont in 1960, I have been an enthusiastic teacher. I began teaching at McMaster University in Hamilton, where I am now an adjunct Associate Professor of Biology, in 1974; my courses have included both introductory and advanced systematic botany and the botanical portion of a course in paleontology. In recent years, my university teaching has been in the less urbanized environment of the Queen's University Biological Station, near Chaffey's Lock, Ontario, where I have presented courses in pteridology and now teach general systematic botany for the Ontario Universities Program in Field Biology. Also, since coming to the Royal Botanical Gardens, I have given courses for the public on plant identification, beginning ornithology, and introductions to the ferns, grasses, and Asteraceae. I lead field trips for plant and bird study in the Royal Botanical Gardens educational program and for such groups as the Field Botanists of Ontario. Each spring I return to the scene of my graduate studies as a leader in the Great Smoky Mountains Wildflower Pilgrimage, and then go to Queen's University Biological Station as an instructor in the Naturalists' Workshop.

Credit for stimulating my interest in the history of botanical exploration should be given primarily to Prof. Joseph Ewan, formerly of Tulane University, now at the Missouri Botanical Garden, Dr. Ronald L. Stuckey, of the Ohio State University, and Dr. Edward G. Voss, of the University of Michigan. The papers in this volume represent studies undertaken on behalf of the *Flora of North America* project, and are the most comprehensive in a succession of studies related to the history of botany and floristic exploration in Canada. Some of my previous studies have dealt with the botanical exploration of parts of the country; others have dealt with the lives of individual career and amateur botanists, and with bibliographic topics.

JAMES S. PRINGLE

Book Reviews

Botany

Flora of North America North of Mexico, Volume 1, Introduction

Edited by Flora of North America Editorial Committee. 1993. Oxford University Press, New York, Oxford xxi + 372 pp., illus. $US 75.00 + mailing.

It was at the Tenth International Botanical Congress in Edinburgh in 1964 that North American botanists first considered launching a comprehensive flora of North America. In August of that year at the annual meeting of the American Institute of Biological Sciences (AIBS) the Council of the American Society of Plant Taxonomists (ASPT) appointed a committee to study the feasibility of such a project.

Nancy R. Morin and Richard W. Spellenberg have written a short introduction describing the history of the Flora North America project, its pilot projects and other activities from 1965 to 1973, its demise because funding could not be committed and its rebirth in 1982. Since that time with its home at the Missouri Botanical Garden work on the flora has forged ahead, and has involved many individuals and institutions.

The enormity of the task is reflected by the extensive response (miraculously) obtained. Partial funding of this project has come from National Science Foundation, The Pew Charitable Trusts, The Caleb C. and Julia W. Dula Foundation, The Surdna Foundation, The Robert and Lucile Packard Foundation, National Fish and Wildlife Foundation, ARCO Foundation, and The William and Flora Hewlett Foundation and member institutions of the Flora North America Association: Canadian Museum of Nature, East Central University, Field Museum of Natural History, Fish and Wildlife Service United States Department of the Interior, Harvard University, Hunt Institute for Botanical Documentation Carnegie Mellon University, Jacksonville State University, Kansas State University, Missouri Botanical Garden, New Mexico State University, New York State Museum, Northern Kentucky University, Royal Ontario Museum, Southern Illinois University, The New York Botanical Garden, The University of British Columbia, The University of Texas at Austin, Université de Montréal, University of Alaska, University of Alberta, University of California, Berkeley, University of California, Davis, University of Iowa, University of Michigan, University of Oklahoma, University of Southwestern Louisiana, University of Tennessee, University of Western Ontario, University of Wyoming, and Utah State University. In addition, the following institutions signed a Memorandum of Cooperation as members of the Flora of North America Association: Arnold Arboretum, Biosystematics Research Institute Agriculture Canada, Carnegie Museum of Natural History, Field Museum of Natural History, Harvard University Herbaria, Hunt Institute for Botanical Documentation, Jacksonville State University, Alabama, Kansas State University, Missouri Botanical Garden, Jardin Botanique de Montréal, National Museum of Natural Sciences (Ottawa) [now the Canadian Museum of Nature], New Mexico State University, Northern Kentucky University, Office of Scientific Authority, U.S. Fish and Wildlife Service, The New York Botanical Garden, Université de Montréal, University of Alaska, University of Alberta, University of California, Berkeley, University of California, Davis, University of Idaho, University of Illinois at Urbana-Champaign, University of Kansas, University of Ottawa, University of Western Ontario, and University of Wyoming.

Following the introductory section the volume is divided into five parts:

Part 1, the Physical Setting encompasses Climate and Physiography by Luc Brouillet and R. David Whetstone and Soils by Donald Steila. Here with much information and references are maps depicting airstream routes, climatic regions, physiography, tectonic areas, position of North America relative to other landmasses from the Cretaceous to the present, deglaciation from the maximum of the Wisconsinan glaciations, surficial geology, bedrock geology, permafrost, physiographic regions, and a distribution map of the orders of soil.

Part 2, Vegetation and Climates of the Past is divided into two parts, History of the Vegetation: Cretaceous (Maastrichtian) — Tertiary by Alan Graham and paleoclimates, paleovegetation, and paleofloras during the Late Quaternary by Paul A. Delcourt and Hazel R. Delcourt. Here too are maps and illustrations accompanying the text together with many references where more detailed information can be found.

Part 3, Contemporary Vegetation and Phytogeography again is divided into two parts: Vegetation by Michael G. Barbour and Norman L. Christensen and Phytogeography by Robert F. Thorne. Barbour and Christensen begin their presentation as follows: "Covering nearly 60° of latitude and 145° of longitude, the North American continent extends through a striking diversity of climates and supports a rich array of vegetation types. Most of the world's major plant formations are represented. Tundra, boreal forest, montane conifer forest, temperate deciduous and evergreen trees, semiarid desert scrub, Mediterranean scrub, and tidal marshes occupy significant portions of the continent. Prominently missing are extremely arid deserts and several tropical grassland, savanna, and forest types.

"The themes we emphasize in this chapter are: (1) relationships between vegetation and regional climate, (2) environmental gradients and episodic stresses that create vegetation gradients over space and time, and (3) the nature of ecotones that exist between all major vegetation types. We begin our survey with tundra vegetation — at the northern limits of plant life — and work clockwise through the continent, to boreal forest, eastern deciduous forest, grassland, desert, woodland, western conifer forest, and coastal vegetation. A map of the major vegetation types of North America north of Mexico is given in Figure 5.1. Because of the map's large scale, it does not show many ecotones, mosaics, or local subtypes of vegetation. Every regional specialist who examines our map will likely find some detail to be in error. We alert the reader to the fact that figure 5.1 represents an oversimplification of nature, and we apologize for necessary local distortions."

Throughout this section are photographs of patterned tundra, various forest types, prairie grassland, deserts, salt marshes, and sand beaches which give the reader an opportunity to see some of the many vegetation types that are discussed.

In the section on phytogeography Thorne uses his own classification for the angiosperms. His family and subfamily circumspections differ somewhat from those of Cronquist whose scheme is used in the taxonomic treatments of the *Flora of North America*. Descriptions are given of the Circumboreal Region divided into Arctic Province and Canadian Province; the North American Atlantic Region divided into Appalachian Province, Atlantic and Gulf Coastal Plain Province, and North American Prairies Province; the Rocky Mountain Region divided into Vancouverian Province and Rocky Mountain Province, the Madrean Region divided into the Great Basin Province divided into four subprovinces and the Caribbean Region. One might find the numbering of these regions confusing until they realize that the missing numbers correspond to regions outside of North America north of Mexico according to the *Floristic Regions of the World* by Armen L. Takhtajan (1986). A map depicting these provinces and subprovinces is provided as well as a map which gives the number of plant families in each of the provinces, territories and states.

Part 4, Humankind and the Flora is divided into four sections: (1) Taxonomic Botany and Floristics by James L. Reveal and James S. Pringle; (2) Weeds by Ronald L. Stuckey and Theodore M. Barkley, (3) Ethnobotany and Economic Botany by Charles B. Heiser Jr.; and (4) Plant Conservation by George Yatskievych and Richard W. Spellenberg.

Reveal and Pringle traced the early collecting of plant specimens by naturalists and those interested in herbs and medicinal plants that found their way back to botanical gardens, and the hands of such botanists in Europe as John Ray, Joseph Pitton de Tournefort and Linnaeus who included North American plants in their writings. It was in 1803 that the first account of North American native plants by Michaux, *Flora Boreali-Americana* was published in North America, and in 1815 Thomas Nuttall published his *Genera of North American Plants*. The authors then traced botanical activities, to modern times in a most interesting manner, wrapped around 29 excellent photographs of such eminent botanists as John Torrey, Asa Gray, Merrit Lyndon Fernald, Ernest Lepage, and Alice Eastwood. They end with the statement "Most who pick up this and the subsequent volumes will find the history of systematics and floristics on every page, for each plant name has a story to tell. Those who look into that story will find wonderful rewards and even greater appreciation of systematics".

Stuckey and Barkley discuss the concepts of weeds, origins, and invasions. They present tables of Ideal Weed Characteristics and Percentage Comparison of Numbers of Foreign Species to Total Numbers of Species since 1950 for Canada, Northeastern United States, and Various Other States of the United States.

Heiser presents information on Wild Food Plants, both those used by the American Indians and those used by immigrants. Then there are Narcotics, Hallucinogens, Stimulants, and Alcoholic Beverages which are derived from plants as well as Medicines, Wood, Ornamentals, and Important Agricultural Crops.

Yatskievych and Spellenberg bring forth the need for preservation of our natural resources for future generations. They express the importance of conserving biodiversity, the ethical and moral obligations of doing so, and the ecological and economic impact. A map depicts the national parks in Canada, Greenland, and the United States. Here too, the need for species conservation is expressed and the contributions made in this direction are discussed in the three countries, as are the present and future chal-

lenges. An appendix gives an example of the diversity of plants in danger of extinction in the continental United States.

Part 5, Classification and Classification Systems is divided into five sections:

(1) Concepts of Species and Genera by G. Ledyard Stebbins, (2) Pteridophytes by Warren H. Wagner Jr. and Alan R. Smith, (3) Gymnosperms by James E. Eckenwalder and A commentary on the General System of Classification of Flowering Plants by Arthur Cronquist, (4) Flowering Plant Families: An Overview by James L. Revel, and (5) Literature Cited by Robert W. Kiger.

Stebbins presents a brief recent history of species concepts and methods of analysis, the problem of defining and delimiting species, growth habit, population structure, and reproduction isolation, and a move toward a broader biological species concept.

Wagner and Smith give a general background of the ferns and fern allies. Eckenwalder discusses the classification of gymnosperms and in particular the three divisions that occur in North America, Cycadophyta, Coniferophyta and Gnetophyta. In these there are disagreements among various taxonomists concerning the familial, generic and species relationships and the arrangement adopted in the flora is a compromise for North America.

Cronquist explains some of the problems in the classification of flowering plants and states that the classification of angiosperms used in the *Flora of North America* is the "integrated system" of A. Cronquist (1981 slightly modified in 1988). He then goes on to describe the Dicota and Monocots and their subclasses. Cronquist then ends with "Nothing can be more certain than that future studies will lead to changes in the system here discussed. I can hope that considerable segments of it are now stable, but only time will tell. Just as we stand on the shoulders of our predecessors, future taxonomists will stand on ours". It is most unfortunate that Arthur Cronquist did not live to see this volume or any of the other volumes that will make up the *Flora of North America*.

James Reveal in his overview of flowering plant families introduces his section by the following: "One of the purposes of the *Flora of North America* project is to present a series of established names at all ranks for extant vascular plants north of Mexico, and thus by its very nature, this work will be a standard by which all future modifications will be judged. The problems are more acute at the generic and specific ranks, but major changes will undoubtedly occur also at the ranks of family and order during the useful life of this and the following volumes". He then proceeds with a brief discussion of earlier systems in the 1800s to the late 1950s, and on the system presented by Cronquist whose sequence is followed in this flora and compares it to recent works of Takhtajan and Thorne in Appendix 2. Appendix 1 portrays the Dicots (Magnoliopsida) with six subclasses and 64 orders and 323 families, and the Monocots (Liliopsida) with 5 subclasses, 19 orders and 66 families.

This volume is completed by a consolidated list of all the works cited by the various authors in their separate sections. This has been done by Robert W. Kirger, Editor.

Those who have contributed to this first volume of Flora North America have done a tremendous job. It is something that will last for many years and will be a most welcome beginning for anyone starting out in the field of botany.

A total of 14 volumes are planned, Volume 2 Pteridophytes and Gymnosperms (1993), Volume 3 Magnoliidae and Hamamelidae, Volume 4 Carophyllidae, Volume 5 Dilleniidae, Volume 6 Rosidae: Rosales and Fabales, Volume 7 Rosidae except Rosales and Fabales, Volume 8 Asteridae: Gentianales, Solanales, Lamiales, Callitrichales, Plantaginales, Volume 9 Asteridae: Scrophulariales, Campanulales, Rubiales, Dipsacales, Calycerales, Volume 10 Asteridae: Asterales, Volume 11 Liliopsida except Poaceae, Volume 12 Liliopsida: Poaceae, Volume 13 Bryophytes and Volume 14 Comprehensive Bibliography and Index. Botanists around the world will welcome these as they are published.

WILLIAM J. CODY

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Flora of North America North of Mexico, Volume 2, Pteridophytes and Gymnosperms, Psilotophyta (Whisk Ferns), Lycopodiophyta (Club-mosses), Equisetophyta (Horsetails), Polypodophyta (Ferns), Cycadophyta (Cycads), Ginkgophyta (Ginkgos), Coniferophyta (Conifers), Gnetophyta (Gnetophytes)

Edited by Flora of North America Editorial Committee. 1993. Oxford University Press, New York, Oxford ix + 475 pp., illus. $US 75.00 + mailing

To put together a work such as this required a tremendous effort from 55 authors, to say nothing of the many reviewers and the editorial staff.

In the introduction is a short outline of the scope of *Flora North America North of Mexico*. "It is a means of identifying plants within the region and as a systematic conspectus of the North American flora". The text includes identification keys, habitat information, geographic ranges, synonomy, descriptions, chromosome numbers, phenological information, and other biological observations.

Separate keys are provided for the Pteridophyte and Gymnosperm families. These are naturally more detailed and perhaps more difficult to follow than such keys that one would find the floras of various regions, states, provinces, or territories because of the larger number of species, genera and families, but seem quite workable.

In this part of the flora for the area north of Mexico 20 families of ferns are recognized, including 65 genera and 345 species. Of these, 14 families, 31 genera and 114 species occur in Canada. Five families including 11 genera and 102 species of fern allies are recognized north of Mexico. Of these, four families, including seven genera and 49 species occur in Canada. Six Gymnosperm families, including 20 genera and 113 species are found north of Mexico, of which 3 families, 10 genera and 27 species occur in Canada.

In the past few years many new treatments of ferns, fern allies and Gymnosperms have been brought forward. Examples of these are the genera *Huperzia*, *Diphasiastrum*, and *Lycopodiella* which were formerly treated at the subgeneric or section level under *Lycopodium*, the recognition of the genus *Aspidotis* which separates the species *californica*, *carlotta-halliae*, and *densa* from the genus *Cheilanthes*, and the separating of *Abies bifolia* from *A. balsamea*, the former extending northward through southwestern Alberta and eastern British Columbia to southeastern Yukon Territory and extreme southwestern District of Mackenzie and the latter through the coastal and subalpine forests of western British Columbia to southwestern Yukon Territory and southern Alaska.

It is inevitable that not all botanists will agree with every treatment but this is a tremendous effort which will be basic to any future studies in the region. The descriptions are quite detailed for the families, genera, and species, and are followed by many interesting and useful comments such as history, relationships, suggestions of what to look for in the field, and references to pertinent literature.

For families, an estimate of the total number of genera and species is provided together with the numbers in the flora and general distribution; for genera the estimated number of species worldwide, with the number in the flora, and general distribution; for species, the habitat, overall range where a species occurs outside of the range of the flora plus a list of provinces and territories in Canada and states in the United States in which it has been found, plus altitudes.

The text is wrapped around small distribution maps upon which the distributions are shaded in a rather sweeping fashion, which obscures the rarity of some species in certain areas and extends over areas in which a species is not known to occur. An example of this is the map of *Polystichum braunii* where the shading covers the extreme southwest corner of the Yukon Territory and its presence there is even mentioned in the text. *Polystichum munitum* is also unfortunately reported in the text as occurring in the Yukon Territory but is not mapped from there although there is a dot on the map just south of the border in northern British Columbia. Not all the species are illustrated but there are some excellent line drawings scattered throughout the book.

Again, this is a tremendous effort and it will be welcomed not only by botanists and students of botany in North America but around the world.

WILLIAM J. CODY

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TABLE OF CONTENTS *(concluded)*

Mailing date of the previous issue 109(2): 12 October 1995

THE CANADIAN FIELD-NATURALIST Volume 109, Number 3 1995

Articles

continued on inside back cover

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Back Numbers and Index

Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club*, 1879-1886, and *The Ottawa Naturalist*, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: A Common Loon, *Gavia immer*, incubating on a nest atop an artificial platform and Western Painted Turtles, *Chrysemys picta bellii*, basking on the nest and on the loon, 17 May 1994, Garfield Lake, Hubbard County, Minnesota. Photograph by R. Dykehouse, USFS. *See* T. Gelatt and J. Kelley, pages 456–458.

The Canadian Field-Naturalist

Volume 109, Number 4 October–December 1995

Distribution and Breeding Status of the White-faced Ibis, *Plegadis chihi*, in Canada

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Goossen, J. Paul, David M. Ealey, Harry Judge, and David C. Duncan. 1995. Distribution and breeding status of the White-faced Ibis, *Plegadis chihi*, in Canada. Canadian Field-Naturalist 109(4): 391–402.

The White-faced Ibis (*Plegadis chihi*) has been annually reported in Canada only since 1974. All records but one are from western Canada and most are from Alberta (68%). The first confirmed Canadian nesting attempt was in 1982, followed by two attempts in 1986 and the first successful nesting in 1992. Movement beyond the normal range may be related to population dynamics, habitat loss and drought. We suggest that this species is a rare summer resident in Canada.

Key Words: White-faced Ibis, *Plegadis chihi*, Canada, breeding, distribution, status.

The White-faced Ibis (*Plegadis chihi*) breeds primarily in the western United States, southern Mexico and South America (American Ornithologists' Union 1983). The published status of this species varies across Canada; it is very rare in British Columbia (Campbell et al. 1990), recently confirmed breeding in Alberta (Koes and Taylor 1992b), a straggler in Saskatchewan (Kreba 1990) and recently confirmed to occur in Manitoba (Koes and Taylor 1990). In this paper, we provide an analysis of reported occurrences of the White-faced Ibis in Canada from 1884 to 1992 and document the first confirmed nest records, previously unpublished.

The earliest confirmed Canadian record of this species was an immature collected in 1907 near Sardis, British Columbia (Table 1). Later, White-faced Ibises were first reported in Alberta, Manitoba and Saskatchewan in 1941, 1975 and 1976, respectively. Ontario has one unconfirmed record — a specimen taken near the Ontario-New York border on 18 September 1908 (see references in Beardslee and Mitchell 1965). The subsequent mount was clearly identified as a White-faced Ibis; however, there was some question as to whether the mounted bird was the one collected on the above date.

In western Canada (Figure 1), there have been about 120 records of the White-faced Ibis during the period 1884 to 1992 (Table 1). We define a record as a report of a single, a group(s) or cumulative observations of a White-faced Ibis(es), seen at a given site within a 10-day period. Where evidence suggests a single bird was observed over a long period, only one record was counted. The species has been seen most frequently in Alberta (68.3% of 123 records), followed by Saskatchewan (18.7%), British Columbia (8.1%), Manitoba (4.1%) and Ontario (0.8%). The number of individuals seen per sighting in western Canada ranged from 1 to 23. In Canada, nesting of White-faced Ibises has been documented only in Alberta (Table 1).

We also classified records by season. Where numerous records over one or more seasons were reported, we summarized these sightings as one record per season. If a season but no month was reported, we assigned the sighting to the appropriate group of months. About 38% of western records were made during spring (April-May), and most (52%) were made in summer (June-August). Only about 10% of the records were from fall (September-November). There was one record during winter (December-March). The seasonal frequency of these records must be interpreted cautiously because of temporal and spatial distributions of birdwatchers (Chapman et al. 1985).

The Glossy Ibis (*Plegadis falcinellus*) is difficult to distinguish from the White-faced Ibis during the nonbreeding season (Kreba 1981; Campbell et al. 1990; Sabo 1992). This difficulty could result in fewer confirmed fall records of either species. However, the relatively few confirmed sightings of Glossy Ibises in western Canada suggest only a small probability of confusing the Glossy Ibis with the White-faced Ibis. Godfrey (1986), who summarized Canadian bird distribution records up to

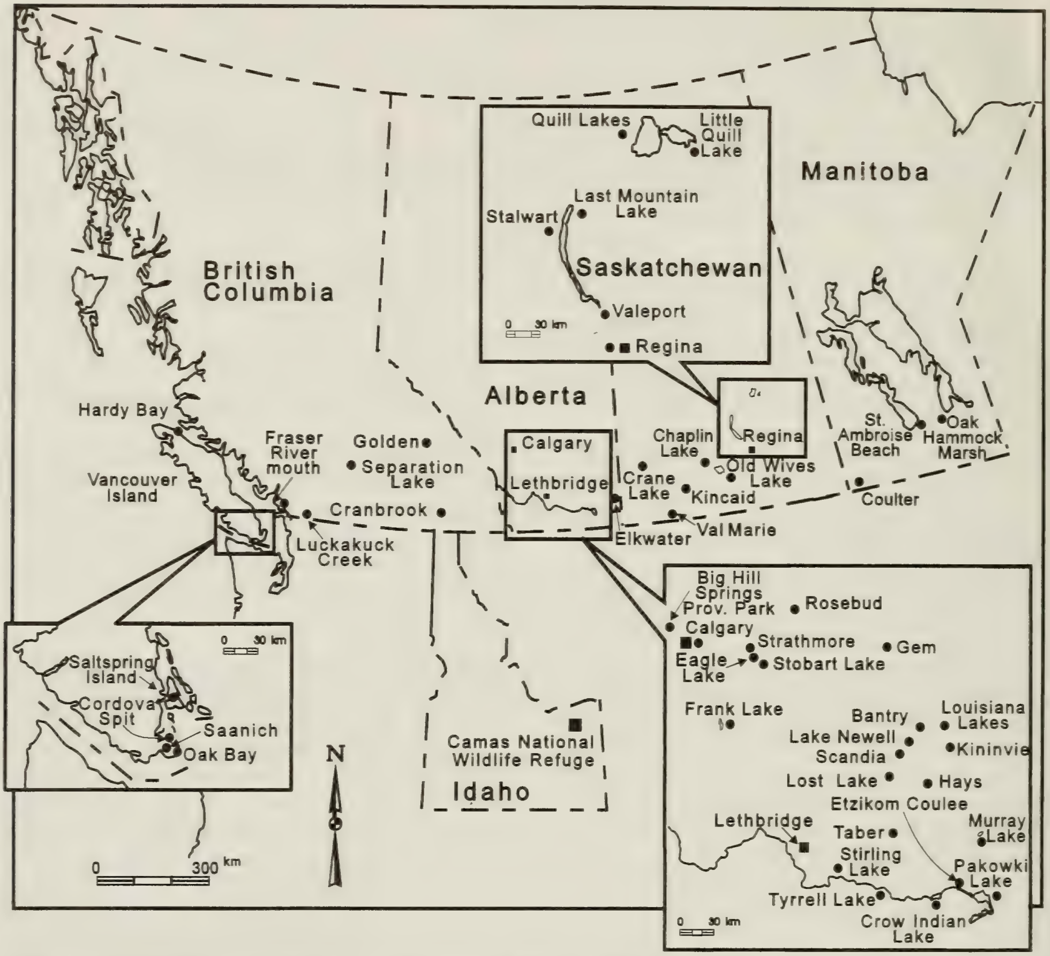

FIGURE 1. Distribution of White-faced Ibis records (●) in western Canada. (One unconfirmed record for eastern Canada [see text]).

December 1984, does not report the Glossy Ibis as occurring in the western provinces. DeSante and Pyle (1986) reached a similiar conclusion with one exception, Saskatchewan, where they considered this species as an extremely rare vagrant. There are nine Glossy Ibis reports from the prairie provinces. Of these, one is confirmed for Manitoba (Gollop 1989; Koes 1991), whereas another, reported as a Glossy Ibis near Langruth, Manitoba (Gardner 1972, 1981; Houston 1972), could be identified only as an ibis sp. (A. J. Macaulay, personal communication). In Saskatchewan, where the Glossy Ibis has been reported six times, the species' occurrence is considered to be hypothetical (Kreba 1990). This species is not listed for Alberta (Ealey 1992), although there is one unconfirmed report of five at Stirling Lake (Schuler 1977). The Glossy Ibis is not listed for British Columbia (Campbell et al. 1990). We recognize that some observers assume that ibises seen in known or plausible White-faced Ibis' range are attributable to this expected species and report sightings as such. Unidentified ibises (*see* Schuler 1977; Gollop 1986; Koes and Taylor 1992b; Smith and Adam *in press*) in the prairies could be either of these two species; however, the probability is greater that they are White-faced Ibises than Glossy Ibises.

Prior to 1982, data from field observations, on at least five occasions, suggested that the White-faced Ibis might breed in southern Alberta. Five White-faced Ibises seen at Pakowki Lake on 1 July 1975 (Table 1) behaved in a manner that suggested possible breeding (Smith and Wallis 1976). Salt and Salt (1976) unfortunately cited the latter date as 3 July 1975 and noted "several White-faced Ibises were observed and photographed in a marshy area of Pakowki Lake and four nests with eggs, believed to

TABLE 1. Reported sightings of the White-faced Ibis in Canada.

Province and Date	Area	Number seen (age)	Remarks	Source
British Columbia				
1884	Saltspring Island	1	specimen[a]	Fannin (1891) cited in Brooks and Swarth 1925; Bent 1926
?	Fraser River mouth	1	specimen[a]	Fannin (1891) cited in Brooks and Swarth 1925
summer of 1902[b]	Luckakuck Creek[c]	1 (immature)	specimen	Brooks 1917; Godfrey 1986; Campbell et al.1990
9, 12 May 1968	Cranbrook	2	photo of one	Eastman 1974; Godfrey 1986
24 May 1982	Saanich	1 (adult)		Mattocks and Hunn 1982; Godfrey 1986; Campbell et al. 1990
24 May 1982	Oak Bay	1	possibly Saanich bird or another	Mattocks and Hunn 1982; Campbell et al. 1990
20 July 1983	Cordova Spit	1 (adult)		Campbell 1983; Campbell et al. 1990
22, 30 May 1985[d]	Separation Lake[d]	1 (adult)		Campbell 1985; Rogers 1985; E. Hennan, personal communication
about 2 November 1986 to 8 May 1987	Hardy Bay	1	photographed	Mattocks and Harrington-Tweit 1987; Campbell et al. 1990
17, 18, 20 May 1988	Golden	up to 3	photographed	Campbell et al. 1990
Alberta				
18 June 1941	Rosebud	1		Kondla et al. 1973
1 June 1964	Strathmore	1 (adult)		Lister 1964; Schuler 1977; G. Freeman, personal communication
11 June 1974	Pakowki Lake	1	first photos	Salt and Salt 1976
11 May 1975	Frank Lake	2	photographed	Salt and Salt 1976; Pinel and Butot 1978; Godfrey 1986; D. Dickson, personal communication
28 May 1975[e]	Crow Indian Lake	6		Schuler 1977
1 July 1975	Pakowki Lake	5-7 (adults)	nesting suspected	Smith and Wallis 1976; W. Smith, personal communication
3 July 1975	Stirling Lake	2 (adults)		G. Freeman, personal communication; Schuler 1977
10 July 1975	Stirling Lake	4[f]	photographed	Schuler 1977; Serr 1975b
15 July 1975	Stirling Lake	2 (adults)		T. Dolman, personal communication
19 July 1975	Stirling Lake	1		Schuler 1977
20 July 1975	Stirling Lake	4		E. Tull, personal communication
24 July 1975[g]	Pakowki Lake	11 (adults)		Smith and Wallis 1976
July 1975	Stirling Lake	3		Schuler 1977
12 August 1975	Stirling Lake	7	5 in a group and 2 singles	Schuler 1977
13 September 1975	Stirling Lake	2		Schuler 1977
11 May 1976	Stirling Lake	1		Schuler 1977
20 May 1978	Pakowki Lake	3 (adults)		Pinel et al. 1991; C. Wershler, personal communication

Continued

TABLE 1. *Continued.*

Province and Date	Area	Number seen (age)	Remarks	Source
1 July 1978[b]	Pakowki Lake	5	unsubstantiated nest record (2 July 1978)	Fitzharris 1980; Anonymous 1979
7 July 1978	Pakowki Lake	1	"reported on several occasions"	Butot 1978a,b; Pinel et al. 1991
late June or early July 1979	Lake Newell	1 (adult)	feeding	A. Fehr, personal communication
10 July 1979	Pakowki Lake	1	photographed	Gollop 1979; Pinel et al. 1991
19 August 1979	Frank Lake	1		Pinel et al. 1991
22 June 1980	Pakowki Lake	5 (adults)		Pinel et al. 1991; C. Wershler, personal communication
11 May 1981	Bantry	3 (adults)		R. Long, personal communication
early June 1981	Pakowki Lake	1 (adult)	flying	D. Petersen, personal communcation
20 June 1981	Pakowki Lake	up to 3	flying	P. Sherrington, personal communication
3 July 1981	Pakowki Lake	1	"down on its head"	Gollop 1981
6 July 1981	Pakowki Lake	1		O. Droppo, personal communication
7 July 1981	Kininvie	4 (adults)		G. Freeman, personal communication
8 July 1981	Kininvie	4 (adults)		T. Sadler, personal communication
30 July 1981	Pakowki Lake	2,4 (adults)	feeding, photos of one	M. Hampshire, personal communication
August 1981	Pakowki Lake	1 or 2 (adults) 1 or 2 (juveniles)	see text	S. Shadick, personal communication
6 May 1982	Kininvie	4 (adults)	feeding, photos	M. Hampshire, personal communication
18 May-18 June 1982	Kininvie	1 or more adults	nest, photos, 3 eggs	M. Hampshire and R. Long, personal communications; this note
23, 28, 30 May 1982	Pakowki Lake	1 or 2		O. Droppo, personal communication
30 June 1982	Pakowki Lake	2		E. Tull, personal communication
June 1982	Louisiana Lakes	2 (adults)		K. Bailey, personal communication
Summer 1982	Kininvie	up to 5	seen almost daily	R. Long, personal communication
11 August 1982	Murray Lake	1 (adult)	flying	K. Bailey, personal communication
30 July 1983	Pakowki Lake	1		Elphinstone 1985a
10 August 1983	Pakowki Lake	1		O. Droppo, personal communication
16 May 1985	Pakowki Lake	1 (adult)		C. Wershler, personal communication
20 May 1985	Calgary	1	photographed	Elphinstone 1985b
29 May 1985	Pakowki Lake	1		Horch 1985
26 May 1986	Pakowki Lake	4 (adults)	flying	this note (Judge)
8 June 1986	Pakowki Lake	1	feeding and flying	R. Dickson, personal communication
10, 11 June 1986	Pakowki Lake	1	nest with 5 eggs; adult, nest and eggs photographed	this note (Judge); Finlay and Finlay 1986
11 June 1986	Pakowki Lake	1	nest with 3 eggs photographed	this note (Judge)
28 June 1986	Pakowki Lake	1 (adult)		H. Pinel and O. Droppo, personal communications

Continued

TABLE 1. *Continued.*

Province and Date	Area	Number seen (age)	Remarks	Source
9 May 1987	Etzikom Coulee	1 (adult)		C. Wershler, personal communication
4 September 1987	near Strathmore	1		Harris 1988
20 September 1987	Eagle Lake	1 (adult)		Elphinstone 1988; Harris 1988; J. Steeves, personal communication
20 September 1987	Stobart Lake area	1 (adult)	probably same as Eagle Lake bird	Elphinstone 1988; Dickson 1988; Harris 1988; C. Wershler, personal communication
7 May 1988	Pakowki Lake	2		D. Hutchinson, personal communication; Semenchuk 1992
28 May 1988	Tyrrell Lake	1 (adult)	feeding	Dolman 1988; Gollop 1988a; T. Dolman, personal communication; Semenchuk 1992
31 May 1988	Taber	1 (adult)		L. Bennett, personal communication
8 or 9 July 1988	west of Elkwater	at least one		Semenchuk 1992; G. Semenchuk, personal communication
26 May 1989	Hays	1	in a flooded ditch	Finlay and Finlay 1989; G. Holroyd, personal communication
1989	Crow Indian Lake	1		Dickson 1989
25 April 1990	Etzikom Coulee	2 (adults)		H. Pinel and O. Droppo, personal communications
26 April - 6 May 1990	Pakowki Lake	up to 3		Koes and Taylor 1990
13 May 1990	Etzikom Coulee	3	feeding	Dickson 1990; R. Dickson, personal communication; Semenchuk 1992
12-14 May 1990	near Big Hill Springs Provincial Park	1		Koes and Taylor 1990; Dickson 1990
17 May 1990	Gem	1 (adult)	feeding in irrigated alfalfa (*Medicago sativa*) field with 100+ Marbled Godwits (*Limosa fedoa*)	R. Nickel, personal communication
May or June 1990	Pakowki Lake	at least one		Semenchuk 1992; G. Semenchuk, personal communication
June 1990	Crow Indian Lake	6 (adults)		H. Judge, personal observation
20 May 1991	Etzikom Coulee	8		Koes and Taylor 1991a; E. Tull, personal communication
31 May, 3 June 1991	Stirling Lake	1 (adult)		T. Dolman, personal communication; Semenchuk 1992
24 June 1991	Pakowki Lake	1 (adult)		S. Shadick, personal communication
17 August 1991	Crow Indian Lake	2		J. and A. Gottfred, personal communication
30 April 1992	Etzikom Coulee	12	flocks of 5 and 12 seen	Dickson 1992a; R. Dickson, personal communication; Koes and Taylor 1992a
22 May 1992	Stirling Lake	1, 4		L. Neish and R. Munro, personal communication; Dickson 1992a

Continued

TABLE 1. *Continued.*

Province and Date	Area	Number seen (age)	Remarks	Source
23 May 1992	Lost Lake	23		Dickson 1992a; R. Dickson, personal communication
23 May 1992	Kininvie	21		Koes and Taylor 1992a
24 May 1992	Stirling Lake	3		T. Dolman, personal communication; Dickson 1992a
28 May 1992	Kininvie	3 (adults)		T. Sadler, personal communication
March, April or May 1992	Kininvie	1		Dickson 1992a
7 June 1992	Stirling Lake	4 (adults)	nest building	L. Bennett, personal communication
9 June 1992	Stirling Lake	2		J. VanderGaast and E. Savoy, personal communication
21 June 1992	Stirling Lake	7 (adults)	nest with one egg and three young; photographed	L. Bennett, personal communication; Dickson 1992b; Koes and Taylor 1992b
25 June 1992	Stirling Lake	3 (adults)	photographed	D. Watson and G. Hale, personal communication
28 June 1992	Stirling Lake	2 (adults)	two nests with four and three young; photographed	L. Bennett, personal communication; Dickson 1992b; Koes and Taylor 1992b
11 July 1992	Stirling Lake	7 (adults); 5 (young)	flightless young out of nests	L. Bennett, personal communication
19 August 1992	Stirling Lake	4	two adults and two juveniles	T. Sadler, personal communication
21 August 1992	Stirling Lake	7		L. Bennett, personal communication
7 September 1992	Stirling Lake	2		D. Baumback, personal communication
10 September 1992	Stirling Lake	1		R. Munro, personal communication
11 September 1992	Scandia	1		D. Watson, personal communication
19 September 1992	Lost Lake	2 (adults)		L. Bennett, personal communication
21 September 1992	Stirling Lake	1 or 2		R. Munro, J. VanderGaast and E. Savoy, personal communication
?	Stirling Lake	several		G. Freeman, personal communication
Saskatchewan				
29, 30 May, 1 June 1976	Stalwart	1	photographed	Lahrman 1976; Godfrey 1986
1 June 1976	Quill Lakes	1		Serr 1976
13 October 1976	Valeport	1	(immature)	Serr 1977; Godfrey 1986
15 May 1977	north end of Last Mountain Lake	3		Callin 1978
August 1977, 1 September 1977	Little Quill Lake	up to 4	seen on several occasions in August	Serr 1978a; Gollop 1978
14 May 1978	Kincaid	2	movie footage	Houston et al. 1981; Serr 1978b
24 June 1984	Old Wives Lake	1		Harris et al. 1985[i]; Gollop 1984
23 April-11 May 1985	north end of Last Mountain Lake	1		Gollop 1985

TABLE 1. *Concluded.*

Province and Date	Area	Number seen (age)	Remarks	Source
				Continued
7 May 1985	north end of Last Mountain Lake	1 (adult)		S. Shadick, personal communication
18 June 1985	Val Marie	2		R. Kreba, unpubl. data in Smith and Adam *in press*
5 June 1986	near Chaplin Lake	3	photographed	Gollop 1986
July 1986	north end of Last Mountain Lake	1		W. Harris fide B. Dale, personal communication; W. Harris, personal communication
20 September 1986	Crane Lake	5		Harris 1987
29 May 1987	north end of Last Mountain Lake	1		Gollop 1987
16 June 1988	Crane Lake	1		Gollop 1988b
21 May 1990	Regina	1		Koes and Taylor 1990
30 May 1990	Regina	2		Koes and Taylor 1990
22, 25-29 June, 1, 3, 4, 6 July 1990	north end of Last Mountain Lake	1-2 (adults)		B. Dale, personal communication
29, 30 June 1990	Crane Lake	1 (adult)	plus one unidentified ibis	S. Shadick, personal communication
8, 9 July 1992	north end of Last Mountain Lake	1 (adult)		B. Dale, personal communication
2 or 3 October 1992	north end of Last Mountain Lake	2 (adults)		B. Dale, personal communication
Manitoba[j]				
26 May 1975	Oak Hammock Marsh	1		Gardner 1975; Hatch 1975a; Serr 1975a; Gardner 1981; Godfrey 1986
31 May 1975[k]	St. Ambroise Beach	1		Hatch 1975a,b; Serr 1975a; Godfrey 1986
2-6 May 1990	Oak Hammock Marsh	1 (adult)	photographed, first confirmed Manitoba record	Anonymous 1990; Koes and Taylor 1990; Koes 1991; R. Koes, personal communication
16 June-14 July 1991	Oak Hammock Marsh	1		Koes and Taylor 1991b
22 July 1991	Coulter	1	identification not confirmed	Koes and Taylor 1991b; S. Davis, personal communication
Ontario				
18 September 1908	Niagara River	1	specimen, unconfirmed	*see* Beardslee and Mitchell 1965

[a] Munro and Cowan (1947) suggested that there was no specimen to confirm the record and that there was no evidence that a specimen had been examined by ornithologists.

[b] Brooks (1917) has the collection date recorded as "sometime in the summer of 1902." Bent (1926) said "fall of 1904." The specimen label, however, reads November 1907 (Campbell et al. 1990).

[c] Luckakuck Creek was formerly known as Luck-a-cuck River and is near Sardis (Brooks and Swarth 1925).

[d] Rogers (1985) incorrectly dated the 30 May sighting as 31 May. Location published as Knutsford (Rogers 1985) but exact location was Separation Lake (E. Hennan, personal communication).

[e] Not clear from Schuler (1977) whether date information received was same date as sighting.

[f] Although Schuler's (1977) references to ibis identities in her publication are not always clear, other authors (Salt and Salt 1976; Pinel et al. 1991) support them as referring to White-faced Ibises.

[g] Salt and Salt's (1976) date of 23 July 1975 is incorrect (W. Smith, personal communication).

[h] Anonymous (1979) reported a date of 1 July 1978, which may be inferred as the date of the unconfirmed nest record; however, information in Fitzharris (1980) suggests it was the following day.

[i] Harris, W., G. Wapple, R. Wapple, K. DeSmet (sic), and S. Lamont. 1985. Saskatchewan Piping Plovers - 1984. Saskatchewan Natural History Society and Saskatchewan Parks and Renewable Resources. 106 pages plus appendix.

[j] A report of a "White-faced Glossy Ibis" at St. Laurent in 1934 is unsubstantiated (Lawrence 1934), as is an ibis sighting at Oak Hammock Marsh on 6 August 1977, which has been ascribed as both a possible Glossy Ibis (Gardner 1981) and a White-faced Ibis (Koes 1991).

[k] Possibly also seen on 18 May 1975 (Hatch 1975b).

be ibis nests, were found." This information appears to have been used to consider the White-faced Ibis as breeding in Alberta (*see* Gollop 1979; McNicholl 1982; Ryder and Manry 1994); however, the nests referred to in Salt and Salt (1976) could not be verified as White-faced Ibis nests (W. Smith, personal communication). DeSante and Pyle (1986) also listed the White-faced Ibis as breeding in Alberta but provided no documentation of any nesting records.

A nest found at Pakowki Lake in July 1978 contained a nestling (a dead young was also found nearby) believed to be a White-faced Ibis in weakened condition (Fitzharris 1980), but the record was declared "unsubstantiated" by the Alberta Ornithological Records Committee (Anonymous 1979). Also at Pakowki Lake, but on 3 July 1981, a White-faced Ibis was observed "with down on its head" (Table 1), giving further evidence of possible breeding in Alberta. One or two adults as well as one or two young were thought to have been seen in early August 1981, also at Pakowki Lake (Table 1). Unfortunately, no other information was recorded and a photograph showed only a profile of a bird (S. Shadick, personal communication).

There have been at least five confirmed nesting attempts by White-faced Ibises in southern Alberta. R. Long (personal communication) observed a White-faced Ibis nesting in a Black-crowned Night-Heron (*Nycticorax nycticorax*) colony at one of the Minor Lakes (referred to as Kininvie F and described by Giroux 1981 and Duncan 1986) near Kininvie on 14 June 1982 (Table 1). Photographs of the nest with three eggs were taken and, upon Long's retreat from the site, a single adult returned to the nest and settled on the eggs after 10 minutes. Later, D. Duncan confirmed that the nest had subsequently been deserted, and on 28 June 1982 the embryos from two of the eggs were collected and later deposited in the University of Alberta Museum of Zoology (collection numbers 5813 and 5814). The nest was located in the midst of an extensive, tall (2.2 m), dense cattail (*Typha latifolia*) stand at the edge of a sizable opening and in approximately 45 cm of water (R. Long, personal communication). The ibis nest was surrounded by nesting Black-crowned Night-Herons, about 5-10 m away. Prior to the 1982 nesting, Duncan recorded five ibis sp. at Kininvie F on 26 July 1981 and 12 August 1981. During the summer of 1982, Long noted that White-faced Ibises were seen almost daily at Ducks Unlimited (Canada) project lakes in the Kininvie area. Subsequent visits were made to the area in 1983 and 1984 by Long, but no ibises were seen, possibly because the lower water levels in those years did not attract the ibises.

On 26 May 1986, one of us (H. Judge), while observing a colony of Black-crowned Night-Herons at Pakowki Lake, noted four adult White-faced Ibises flying above the herons. Judge searched the surrounding area for ibis nests, but only Black-crowned Night-Heron nests were located. On 10 June 1986, as he waded through the same heron colony, he saw a White-faced Ibis flush from the marsh and subsequently found an ibis nest containing five eggs. He photographed the adult at the nest on the following day. That same day, Judge flushed another ibis at Pakowki Lake and located a second White-faced Ibis nest. This nest contained three eggs. Both nests were not visited again.

During 1987-1991, no nesting was reported by Alberta bird atlassers (Semenchuk 1992). Then in 1992, the first confirmed successful nesting of the White-faced Ibis in Canada was documented at Stirling Lake by L. Bennett (Dickson 1992b). Unfortunately, this record was published by Bain and Holder (1992) erroneously as the "first photographic record of White-faced Ibis breeding" in Alberta. On 7 June 1992, Bennett (personal communication) observed four adults nest-building. On a return visit, 21 June 1992, he observed seven adults and found a nest containing one egg and three young. On 28 June 1992, this nest had four young, whereas a second nest that was found the same day, about 20 m from the first nest, had three young (not two as indicated by Anonymous 1992), which were photographed by Bennett. He believed these latter two nests were different from the nests being built on 7 June 1992. The nests, the bottoms of which touched the water, were constructed "of dried reeds attached to the standing reeds" (L. Bennett, personal communication) and reached a height of 20-30 cm above water. On 11 July 1992, Bennett returned to Stirling Lake and observed seven adults and five young in the vicinity of the two nests. Photographs documenting the 1982, 1986 and 1992 nestings have been deposited at the Provincial Museum of Alberta in Edmonton.

The reports of a single immature bird, in both British Columbia and Saskatchewan (Table 1), may reflect local breeding attempts or dispersal. There is no evidence of this species breeding in Manitoba.

In the states adjacent to Canada, White-faced Ibises breed regularly only in Idaho (J. Booser and A. Sprunt, IV. 1980. A literature review and annotated bibliography of the Great Basin/Rocky Mountain population of the White-faced Ibis. Unpublished report for the United States Fish and Wildlife Service, Portland, Oregon. 134 pages). The nearest active colony to Alberta is located at the Camas National Wildlife Refuge (United States Fish and Wildlife Service 1985a; Taylor et al. 1989), about 600 km south of Pakowki Lake (Figure 1). No ibis nesting attempts are known for Washington (Booser and Sprunt 1980), but breeding is suspected in Montana (Serr 1975b) and has been confirmed in both North Dakota (Serr 1978c, 1979) and Minnesota (Peabody 1896).

Drought, drainage, flooding, habitat loss (United States Fish and Wildlife Service 1985b) and eggshell thinning (Kingery 1976) have influenced White-faced Ibis populations. During the mid-1970s, White-faced Ibis numbers declined in portions of the United States (Zimmerman 1975). Sufficient concern was expressed that the species was put on "The Blue List" of potentially threatened species in 1971 (Anonymous 1971). The White-faced Ibis was delisted in 1979 because of little apparent concern over its status (Arbib 1979). The United States Fish and Wildlife Service, however, suggested that if no action was taken to eliminate threats, or if the species was not managed, the population in the Great Basin area might become threatened or endangered (United States Fish and Wildlife Service 1985a,b). Nevertheless, a recent analysis of Christmas Bird Count information suggested that the White-faced Ibis has been increasing significantly in the United States (Butcher 1989). The increase in sightings from the Northern Great Plains in Canada (Table 1) and the northern United States (Serr 1978b), the eastward expansion (Jackson and Cooley 1978) and breeding in Alabama (Imhof 1982), as well as the reappearance of nesting pairs at former breeding locations in California (Campbell et al. 1985; Ivey and Severson 1984) suggest that this ibis' range is expanding (Sabo 1992) and recolonization is occurring.

Why has the White-faced Ibis expanded its breeding range northward into Canada? Unfortunately, as is the case with most avian pioneers, there is little information on origin. Factors thought to contribute to Glossy Ibis' range expansion, such as early breeding age and population growth (Miller and Burger 1978), may also be important in White-faced Ibis' range expansion. The impetus to move may also be related to agricultural drainage of wetlands (Burger and Miller 1977), flooding of traditional breeding sites (Ivey et al. 1988) or drought (Ryder 1967), all of which could cause ibises to search for suitable habitat. The appearance of White-faced Ibises may also be related to weather such as strong winds (Hatch 1975a).

High population levels in the Great Basin area, which have been associated with abundant water, may have facilitated pioneering efforts (B. Sharp, personal communication). Alternatively, flooding of traditional breeding sites may also cause ibises to relocate as suggested by Ivey et al. (1988). They suspected that increased numbers of ibises in Oregon were partly a result of Utah birds relocating after the nesting habitat in the Great Salt Lake marshes was flooded. The substantial decline in the Great Salt Lake breeding population during 1982-1985 (D. Paul, personal communication in Ivey et al. 1988) coincided with this possible relocation to Oregon (Ivey et al. 1988). The timing of the flooding in the Great Salt Lake marshes, along with the population reduction there, closely matches the timing of the ibis nestings in Alberta in 1982 and 1986.

Dispersal following the breeding season (Farrand 1983; Robertson 1977) is not a major factor in range expansion of this species, as is indicated by the few immatures and adults seen in the summer or fall (Table 1). In South America, however, there is some evidence that White-faced Ibises banded as nestlings and recovered in their first year move greater distances than older ibises (Olrog 1975). Miller and Burger (1978) speculated that northern colony establishment by the Glossy Ibis may be assisted by individuals at the periphery of the species' range. Such a role may be valid for the White-faced Ibis, whose pioneers are first year or older birds that wander northward in spring (Table 1). Ryder (1967) noted that, north of the usual nesting range of this species, the number of pre-breeding White-faced Ibis records was almost four times the number of post-breeding records. However, he acknowledged that temporal observer bias might be a complicating factor.

The apparent association between breeding White-faced Ibises and Black-crowned Night-Herons (Peabody 1896; Ivey and Severson 1984; this paper) may have contributed to the range expansion of this ibis. Benefits from this social attraction are unknown; however, the presence of nesting Black-crowned Night-Herons may signal favourable nesting conditions to ibises. Black-crowned Night-Herons were not documented in Alberta until 1957 (Lister 1964) or 1958 (Salt 1961) and the circumstances of their arrival in the province are unknown (Wolford 1966). Knowledge of the occurrence and status of the White-faced Ibis may be increased by periodic monitoring of Black-crowned Night-Heron nesting colonies.

Managed wetlands may serve as important footholds for birds attempting to pioneer new areas (Goossen et al. 1982). Similarly, irrigation in Alberta may facilitate range expansion of ibises (Schuler 1977), as suggested by their high use of irrigated areas (Bray and Klebenow 1988). Wolford (1966) believed that the development of irrigation and Ducks Unlimited impoundments in southern Alberta permitted Black-crowned Night-Herons to invade Alberta, because these wet areas provided feeding and nesting habitats, respectively. About 1900-1925, irrigation districts were established in southern Alberta (Keith 1961). In 1917, irrigation began in the Eastern Irrigation District of southern Alberta, in the vicinity of the Kininvie area (Wyatt et al. 1937). Thirty-one years later, Ducks Unlimited began its program of restoring or enhancing lakes (Leitch 1978). In 1941, the first White-faced Ibis was reported near Rosebud, Alberta, in or near the Western Irrigation District. The first confirmed Canadian nesting of the White-faced Ibis (this paper) was in a Ducks Unlimited (Canada)

impoundment in the Kininvie area (Giroux 1981). Glossy Ibis and ibis spp. sightings have also been noted on Ducks Unlimited projects in Saskatchewan (Gollop 1986).

Breeding site philopatry appears to be low in the White-faced Ibis (Ryder 1967). Fidelity would be an asset to increasing the size of a colony and promoting subsequent colony survival. However, the bird's mobility (Ryder 1967) and its opportunistic response to suitable foraging and breeding habitat (Booser and Sprunt 1980) may work against attachment to a particular site.

Applying the status standards in Gardner (1981), we suggest that the White-faced Ibis in British Columbia is an occasional visitant during any season; in Alberta, a rare summer resident; in Saskatchewan, an occasional visitant during spring, summer and fall; and in Manitoba, accidental. Because it has been seen annually in Canada from 1974 to 1992 and is known to have nested successfully (Table 1), we suggest that the White-faced Ibis should be designated a rare summer resident in Canada.

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The Distribution of Small Mammals on Cultivated Fields and in Rights-of-way

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Marinelli, Lui, and Dick Neal. 1995. The distribution of small mammals on cultivated fields and in rights-of-way. Canadian Field-Naturalist 109(4): 403–407.

The distribution of small mammals in four wheat and four barley fields near Saskatoon, Saskatchewan, was estimated from 140 different transects and 9240 trapnights. Trapping was initiated soon after fields were sowed, and was terminated when the wheat and barley were at approximately the 8- to 10-leaf stage. Overall, small mammals appeared to be evenly distributed between rights-of-way and either field type. However, Deer Mice (*Peromyscus maniculatus*, n = 122) did not show any avoidance behaviour to the wheat or barley fields, while Meadow Voles (*Microtus pennsylvanicus*, n = 40) appeared to avoid the fields. The difference between mice and vole distributions may be attributed to converse activity strategies (i.e., nocturnal versus diurnal) and the tendency to construct runways by voles. The general avoidance of cultivated fields by Meadow Voles may suggest that they have a lower risk of herbicide exposure than deer mice.

Key Words: Deer Mouse, *Peromyscus maniculatus*, Meadow Vole, *Microtus pennsylvanicus*, space use, right-of-way, wheat field, barley field, Saskatchewan.

Small mammals are a major food source for a variety of avian and mammalian predators. Typically, they attempt to reduce the risk of predation by being cryptic, avoiding open areas, and confining most of their activity to areas of vegetative cover and underground burrows (Getz 1985).

A cultivated farm field is a highly dynamic environment for small mammals. It is often devoid of any adequate cover, the soil is disturbed on a periodic basis by tilling, and food resources exhibit dramatic seasonal fluctuations. Agricultural fields are often sprayed for agricultural pests which can have detrimental effects on non-target species. Gregory et al. (1993) reported that insecticides can affect the reproductive success of mice species. Similar effects were felt by some bird species that nest on (Nicholson and Richmond 1985) or near agricultural fields (Odderskaer and Sell 1993) as a result of exposure to insecticides and fungicides. For these reasons, we would predict that cultivated farm fields may be avoided by small mammals for much of the year.

The strips of land (i.e., rights-of-way) that separate farm fields and grid roads often represent the only permanent cover in large expanses of farm land in the prairies. Small mammals might tend to favour such cover (Getz 1985). However, because these rights-of-way are narrow, terrestrial predators can concentrate their search effort on these strips, affecting the suitability of the rights-of-ways (Shalaway 1985; Basore et al. 1986; Camp and Best 1994).

It is not clear how small mammals utilize farm fields and rights-of-way. Do they tend to avoid fields when food and cover are lacking (i.e., pre-emergence), but expand their space use into the fields when foliage is available as a food source and cover (i.e., post-emergence)? At emergence, seedlings are a concentrated food source, however, herbicide-spraying programs often correspond to plant emergence. The effects of herbicide spraying on small mammals is poorly understood, as is the potential risk of exposure that different species may experience based on their space-use patterns.

Our objective was to determine the distribution of small mammals in cultivated fields around the time of plant emergence, when seedlings are available as food but fields have been sprayed with herbicides, and in adjacent rights-of-way. Comparing distributions may suggest the risk to small mammals of herbicide exposure.

Methods and Materials

Small mammal distributions were determined by snap-trapping along transects in wheat and barley fields and in adjacent rights-of-way. From 29 May to 28 June, 1993, 140 different transects were established on four wheat (n = 80 transects) and four barley (n = 60 transects) fields. The wheat fields were approximately 3 km northeast of Saskatoon, Saskatchewan; barley fields were approximately 6 km southeast of Saskatoon.

Transects were established on the side of fields which had grid-road access. At each location, a transect was situated in the field, perpendicular to the grid road (i.e., FIELD TRANSECT), and a second transect was situated parallel to the grid road, in the grass edge between the field and the grid road (i.e.,

RIGHT-OF-WAY TRANSECT). Rights-of-way are narrow ecotones (< 5 m wide) containing a mixture of native and non-native grasses, alfalfa, and various species of shrubs. Field transects were started 10 m from the edge of the field. Field and right-of-way transects consisted of 11 stations, 10 m apart, with two "Museum Specials" snap-traps at each station. The traps were baited with peanut butter. Field transects were a minimum of 100 m apart.

Transects were run for three days to maximize the chance that the majority of individuals in the immediate area were captured. At each capture, date, field (i.e., wheat or barley), cover (i.e., field or right-of-way), transect number, station number, species, age (adult or juvenile), and sex were recorded.

Wheat and barley fields were sprayed by field owners with post-emergent broadleaf and grass wheat herbicides (i.e., Triumph+, Express Pak, Buktrol). Half of the wheat and barley fields were trapped before spraying and the other half were trapped after they had been sprayed. The rights-of-way were not sprayed.

Chi-square tests, using Yates' correction, were used for all statistical analyses. The effect of spraying on the distribution of small mammals was determined by comparing the number of captures on field transects before and after spraying, between wheat and barley fields. Only adults were used in this analysis because they were present in the fields before and after spraying.

The effect of cover was determined by comparing the total number of small mammals captured in rights-of-way and in wheat and barley fields. To assess the effect of proximity to rights-of-way, we compared captures along field transects, from station 1 (i.e., 10 m from rights-of-way) to station 11 (i.e., 100 m from rights-of-way). A *P*-value less than or equal to 0.05 was judged to be significant. The likelihood of correctly rejecting the null hypothesis (i.e., power) was determined for all statistical results. A medium effect size (w = 0.30; Cohen 1988: chapter 7) was used for nonsignificant results, while the observed effect size was used for significant results.

Results

The distribution of small mammals in and adjacent to wheat and barley fields were estimated from 9240 trapnights (Table 1). During the study, we captured 170 small mammals: 122 Deer Mice (*Peromyscus maniculatus*), 40 Meadow Voles (*Microtus pennsylvanicus*), 3 Thirteen-lined Ground Squirrels (*Spermophilus tridecemlineatus*), 2 Masked Shrews (*Sorex cinereus*), 2 Jumping Mice (*Zapus hudsonius*), 1 Northern Pocket Gopher (*Thomomys talpoides*).

The application of herbicides on barley and wheat fields did not negatively effect the number of small mammals captured. The number of small mammals caught before (n = 31) and after (n = 37) the application of herbicide was contingent on the field trapped (X^2 = 4.9, df = 1, P = 0.03, *power* = 0.99). In barley fields, more small mammals tended to be captured after (n = 23) than before (n = 12) spraying (X^2 = 5.1, df = 1, P = 0.02, *power* = 0.43). In wheat fields, we found no significant difference (X^2 = 1.4, df = 1, P = 0.24) between the number of captures before (n = 21) and after (n = 14) spraying, although we only had moderate ability (*power* = 0.43) to detect a medium effect size. Small mammal abundance appeared not to have been adversely affected by spraying of fields and, accordingly, the number of captures before and after spraying were combined in subsequent analyses.

In both wheat and barley fields, cover did not appear to affect the overall distribution of small mammals. Similar numbers of small mammals were caught in fields and rights-of-way (X^2 = 0.16, df = 1, P = 0.70, *power* = 0.97; Figure 1). The few juveniles

TABLE 1. Summary of the trapping effort (i.e., trapnights, TN) and captures of deer mice (*Peromyscus maniculatus*), meadow voles (*Microtus pennsylvanicus*), and all other small mammals in wheat (n=4) and barley (n=3) fields. Effort and captures were partitioned between before and after fields were sprayed.

	Wheat							
	Field (TN)	Captures			Rights-of-way (TN)	Captures		
		Mice	Voles	Others		Mice	Voles	Others
Before spraying	1320	24	0	0	1320	17	7	0
After spraying	1320	20	0	0	1320	13	5	3
	Barley							
	Field (TN)	Captures			Rights-of-way (TN)	Captures		
		Mice	Voles	Others		Mice	Voles	Others
Before spraying	990	10	1	0	990	5	6	0
After spraying	990	22	5	0	990	11	16	5

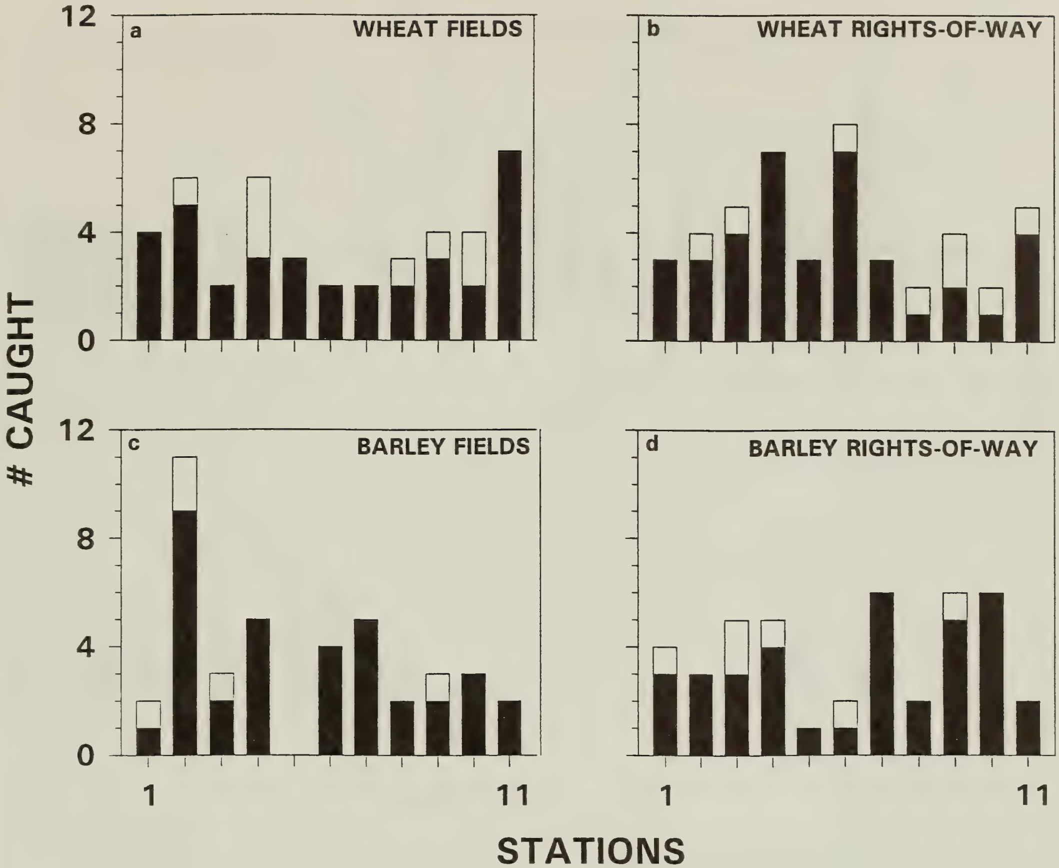

FIGURE 1. Total number of small mammals captured at each snaptrap station on wheat- and barley-field and right-of-way transects near Saskatoon, Saskatchewan, 1993. Solid bars represent number of adults caught and open bars represent juveniles. Among field transects, station 1 is 10 m from rights-of-way and station 11 is 110 m from rights-of-way.

captured were trapped all along the transect and did not appear to avoid either field (n = 13) or right-of-way (n = 14, X^2 = 0.09, df = 1, P = 0.99, *power* = 0.35; Figure 1).

The number of small mammals captured in wheat and barley fields were independent of location along field transects (X^2 = 2.8, df = 4, P = 0.59, *power* = 0.55). Similar numbers of small mammals were captured 10 m from rights-of-way (i.e., station #1) and 110 m (i.e., station #11; Figure 1). However, the few Meadow Voles that were captured on field transects were caught close to the rights-of-way (Figure 2).

Considering the two most frequently captured species (i.e., Deer Mice and Meadow Voles), the number captured in fields and rights-of-way was dependent on the species (X^2 = 26.2, df = 1, P <0.01, *power* = 0.99; Figure 2). Significantly more Deer Mice were caught in fields than in rights-of-way (X^2 = 7.8, df = 1, P < 0.01, *power* = 0.79), while significantly fewer Meadow Voles were caught in fields than in rights-of-way (X^2 = 19.6, df = 1, P < 0.01, *power* = 0.99).

Discussion

Overall, the distribution of small mammals was not significantly different between rights-of-way and either wheat or barley fields. On field transects, small mammals were just as likely to be caught at station 1 (i.e., 10 m from right-of-way) as they were at station 11 (i.e., 110 m from right-of-way).

Mice and voles were the small mammals most commonly captured during this study, but their distributions in wheat and barley fields were significantly different. Voles appeared to avoid cultivated fields. When they were captured on fields, they were captured close to rights-of-way. The lack of adequate cover in fields and the diurnal activity of voles may explain their tendency to avoid fields during this study. Vegetative cover is an important compo-

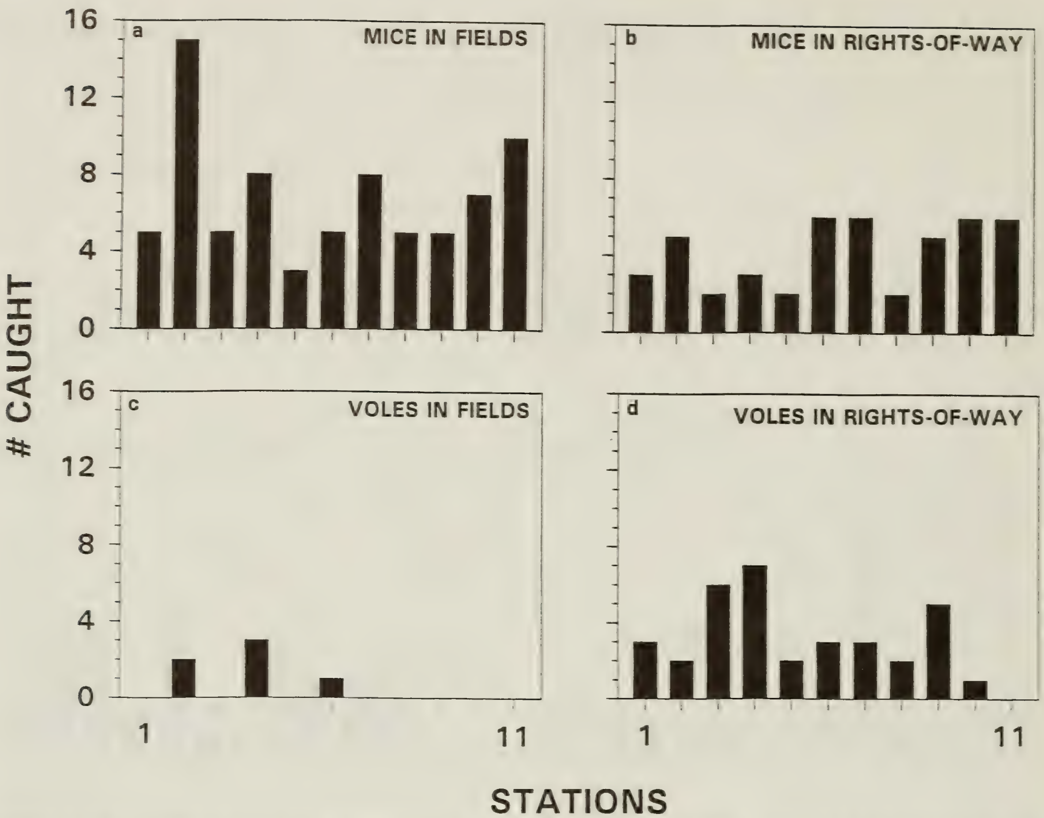

FIGURE 2. Total number of mice and voles captured at each snaptrap station on wheat- and barley-field and right-of-way transects near Saskatoon, Saskatchewan, 1993.

nent of suitable vole habitat (Getz 1985; Merkens et al. 1991). Voles use runways year-round that they create by cutting down vegetation along consistently used pathways. The lack of vegetation in wheat and barley fields may affect the ability of voles to create runways, thereby making fields less suitable. As wheat and barley crops mature, or after swathing, voles may begin to use fields to take advantage of a food source (i.e., wheat and barley seeds).

In contrast, nocturnal mice did not appear to avoid wheat or barley fields, nor did they tend to remain close to rights-of-way. Nocturnal activity may allow mice to use fields while remaining cryptic, although within this period, nocturnal rodents show a preference for dark rather than bright nights (Kaufman and Kaufman 1982; Travers et al. 1988). It is unclear if mice located nests within fields during this study or if their nests were in rights-of-way and fields represented just one aspect of mice space-use.

The apparent lack of avoidance of cultivated fields by Deer Mice would suggest that they had a higher risk of herbicide exposure than Meadow Voles, which appeared to restrict their activity to rights-of-way. The use of fields by Deer Mice may be the result of their tendency to be habitat generalists, as well as a lack of suitable, noncultivated habitat which can affect species abundance (Yahner 1982). In our case, the generalist strategy may have put Deer Mice, and not Meadow Voles, in risk of exposure to herbicides.

Exposure to herbicides could result in death or in the concentration of toxins within Deer Mouse tissues. In the latter case, the effects of the herbicide could have long term effects (i.e., reduced reproductive success) or indirect effects on their predators. Due to the nocturnal nature of Deer Mice, predators such as owls would presumably be at a greater risk of indirect exposure to herbicides than diurnal predators (i.e., hawks). Owls are at the top of their food chain and are therefore especially liable to accumulate large amounts of toxins which concentrate at successive steps in the food chain (Newton 1979: page 229).

Agricultural practices on the prairies have led to extensive habitat fragmentation and, consequently, patches of natural habitat have become prominent

structural features of landscapes (Forman and Gordron 1986; Simberloff and Abele 1982; Wilcox and Murphy 1985). These agricultural practices force certain small mammal species onto cultivated fields which may serve as ecological sink environments and may expose them to lethal measures of pest control.

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Utilisation du Territoire du Nouveau-Québec par l'Oie des Neiges, *Chen caerulescens*, en Période de Migration

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Le Hénaff, Didier, Réginald Ouellet, Michel Lepage, et Charles Maisonneuve. 1995. Utilisation du territoire du Nouveau-Québec par l'Oie des neiges, *Chen caerulescens,* en période de migration. Canadian Field-Naturalist 109(4): 408–412.

Des observations effectuées dans le cadre d'inventaires aériens de Caribous (*Rangifer tarandus caribou*) réalisés en 1975, 1977, 1983 et 1985 confirment que des Oies des neiges (*Chen caerulescens*) effectuent des arrêts réguliers au Nouveau-Québec au cours des migrations printanières et automnales. Les volées observées sont réparties sur l'ensemble d'un vaste territoire. Des densités de 0,3 oiseau/km de ligne de vol ont été observées au printemps, tandis que les densités obtenues à l'automne ont varié de 1,3 à 10,0 oiseaux/km. Les oies s'arrêtent sur les sommets dégarnis des plateaux de la toundra forestière et au-delà de la limite des arbres dans la toundra arctique où elles s'alimentent vraisemblablement de fruits. Les oiseaux effectuant cette halte semblent appartenir aux deux sous-espèces *atlantica* et *caerulescens*.

Observations made during aerial caribou (*Rangifer tarandus caribou*) surveys carried out in 1975, 1977, 1983 and 1985 confirm that Snow Geese (*Chen caerulescens*) make regular stops in Nouveau-Québec during their spring and fall migrations. The observed flocks are distributed across the whole territory. Densities of 0,3 birds/km were obtained during the spring surveys, while those obtained during the fall surveys varied from 1,3 to 10,0 birds/km. Snow geese stop on the hilltops of the forest tundra as well as north of the tree-line in the Arctic tundra where they seem to feed on small fruits. Birds making this stopover seem to belong to both subspecies *C. c. atlantica* and *C. c. caerulescens.*

La Grande Oie des neiges (*Chen caerulescens atlantica*) niche dans le nord-est de l'Arctique canadien et le nord-ouest du Groenland et hiverne dans les états américains qui longent la partie centrale de l'Atlantique (Bellrose 1980; Palmer 1976). L'entière population de cette espèce effectue une halte d'environ 6 semaines le long du Saint-Laurent au cours des migrations tant printanières qu'automnales (Lemieux 1959). Malgré certaines mentions anecdotiques concernant l'existence d'une autre halte dans la péninsule de l'Ungava (White et Lewis 1937; Anonyme 1981), la durée de cette halte et les limites géographiques du territoire fréquenté étaient jusqu'à maintenant méconnus.

En 1975, le ministère du Loisir, de la Chasse et de la Pêche (M.L.C.P.) entreprenait un programme d'inventaires aériens sur le territoire du Nouveau-Québec afin de délimiter les aires de vêlage et assurer le suivi des populations de caribous (*Rangifer tarandus caribou*). Au cours de ces inventaires, de nombreuses volées d'oies des neiges ont pu être observées sur les plateaux toundriques survolés. Cet article vise à faire état de ces observations et à souligner l'importance de ce territoire pour la Grande Oie des neiges au cours de ses migrations.

Matériel et Méthodes

Le territoire couvert lors de nos inventaires recoupe les trois grands biomes de végétation caractéristiques du nord du Québec (Payette 1983). Dans la partie sud, la forêt boréale est caractérisée par un couvert forestier continu, interrompu uniquement par la présence de tourbières. La toundra forestière située plus au nord se distingue par un couvert forestier plus clairsemé et décroissant graduellement vers le nord, entremêlé d'importants peuplements d'éricacées et tapis de lichens sur les sites où les conditions édaphiques ne sont pas favorables à la croissance des arbres. La limite des arbres, qui s'étend d'est en ouest le long du 58° de latitude nord, marque ensuite le passage vers la toundra arctique. Celle-ci est dominée par des landes recouvertes de bosquets d'éricacées épars et rabougris sur un tapis de lichens.

Au cours des printemps 1975, 1977 et 1983, les inventaires ont été réalisés (entre le 28 mai et le 8 juin) en avion bimoteur de type DC-3, à une altitude de 150 à 200 m et à une vitesse moyenne de 220 km/h. En 1975, 22 virées équidistantes de 16 km ont été survolées, couvrant un territoire de 160 000 km^2. Celui-ci était délimité par la rivière Caniapiscau, la Baie d'Hudson et les latitudes 55°20′ et 58°20′ nord

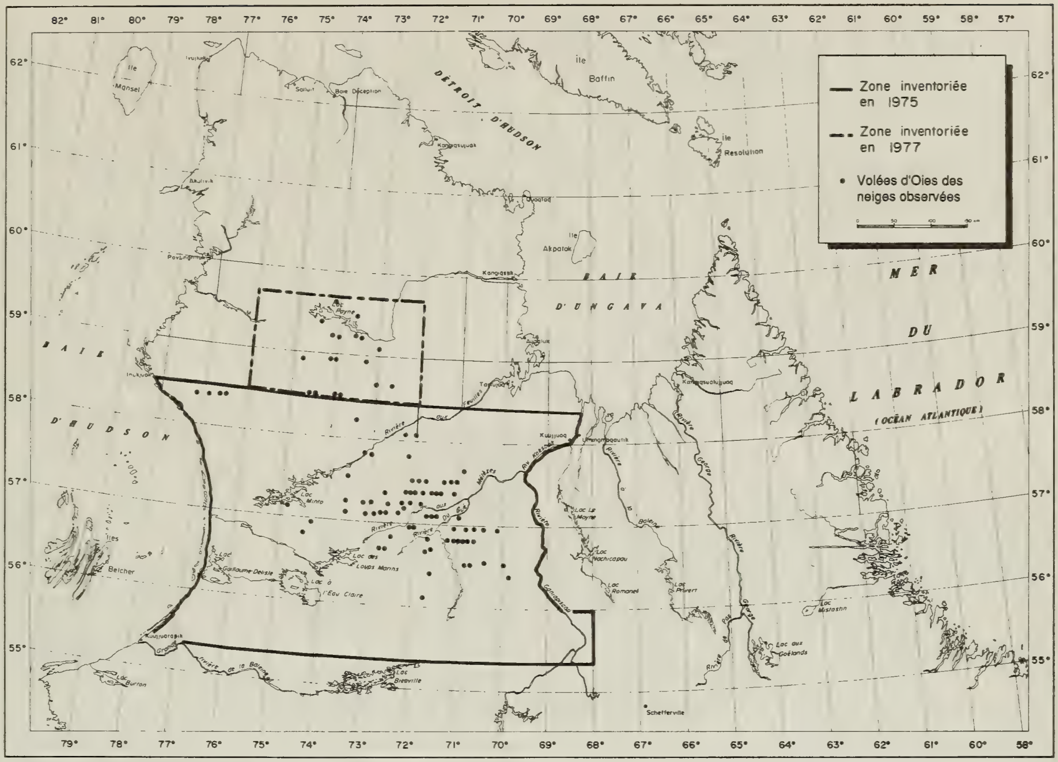

FIGURE 1. Localisation des volées d'Oies des neiges observées au Nouveau-Québec au cours des printemps 1975 et 1977.

(Figure 1). En 1977, une superficie de 25 000 km^{2}a été couverte au moyen de 10 virées équidistantes de 20 km. La zone inventoriée se situait au nord immédiat de la précédente, entre les longitudes 72° et 76° ouest et les latitudes 58°20′ et 59°40′ nord. Une partie de cette même zone (14 000 km^2) était à nouveau survolée au cours du printemps 1983 (Figure 2). La distance entre les 19 virées effectuées était alors de 8 km. À l'automne 1985, des inventaires ont été réalisés dans la région couverte en 1975. Deux lignes de vol d'environ 125 km chacune ont alors été effectuées en hélicoptère, à moins de 100 m d'altitude, près des rivières aux Feuilles et aux Mélèzes (Figure 2). Le nombre d'individus en phase de coloration bleue a été noté au cours de ces derniers inventaires.

Les observations ont été localisées au moyen de systèmes de navigation (système I.N.S. de Lipton en 1975 et 1977, et de type Omega en 1983). Le nombre d'individus n'a cependant pas été déterminé dans les volées observées en 1983, l'emphase du travail ayant été axée sur le caribou.

Résultats et Discussion

Les volées d'Oies des neiges observées au cours des inventaires printaniers étaient réparties inégalement sur l'ensemble du territoire couvert (Figures 1 et 2). Aucune volée n'a été observée au sud du 56° nord, et très peu ont été vues à l'ouest du 75° ouest. Lors des inventaires réalisés en 1975 et 1977, une moyenne de 0,3 oiseau/km de vol a été obtenue (Tableau 1). Les oies étaient totalement absentes de la zone de la forêt boréale. Elles étaient abondantes dans la toundra forestière, où elles étaient surtout concentrées sur les plateaux toundriques dégarnis d'arbres et de neige, de même qu'au-delà de la limite des arbres dans la toundra arctique. Les oies étaient généralement observées au sol et s'envolaient à l'approche de l'avion pour s'éloigner rapidement, sans toutefois prendre de l'altitude. De nombreuses taches d'un rouge vif éclaboussaient les plaques de neige environnantes, résultant vraisemblablement des défécations d'oies ayant fait une consommation importante de fruits.

Près de 10 individus ont été observés par km de vol lors de l'inventaire réalisé le 30 septembre 1985, ce nombre étant réduit à 1,3/km lors de l'inventaire du 11 octobre (Tableau 1). À l'approche de l'hélicoptère, les oies prenaient panique et s'envolaient de façon désordonnée, pour ensuite revenir sur le site initial après le passage de l'aéronef. Des vérifica-

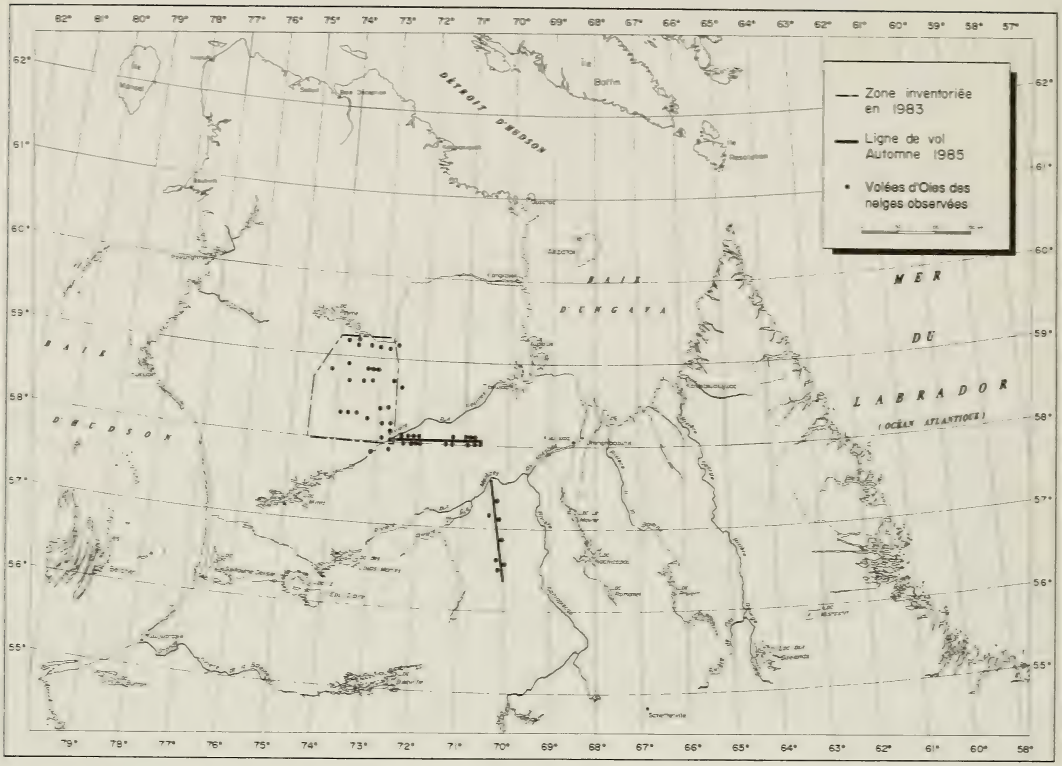

FIGURE 2. Localisation des volées d'Oies des neiges observées au Nouveau-Québec au cours du printemps 1983 et de l'automne 1985.

tions effectuées au sol sur des sites où les oies avaient été observées ont permis de constater l'abondance de fruits de *Vaccinium vitis-idaea* L. et de bleuets (*Vaccinium* sp.). Plusieurs tiges de ces plantes avaient été dégarnies de ces fruits, ces derniers ayant vraisemblablement été consommés par les oies.

TABLEAU 1. Nombre de volées et d'individus d'Oies des neiges observés lors d'inventaires aériens effectués au Nouveau-Québec.

Année	Période	Distance parcourue (km)	Nb de volées	Nb d'individus
1975	28 mai au 8 juin	11 000	75	3156
1977	29 mai au 3 juin	3 300	20	968
1983	31 mai au 4 juin	2 000	28	n.d.[3]
1985	30 septembre[1]	110	19	1085
	11 octobre[2]	195	7	255

[1]Rivière-aux-Feuilles (est-ouest)
[2]Rivière-aux-Mélèzes (nord-sud)
[3]Pas de dénombrement

Le départ des oies de l'estuaire du Saint-Laurent vers le nord s'effectue toujours de façon rapide et synchronisée (2-3 jours) au cours des derniers jours de mai: 20-22 mai (Gauthier et al. 1992), 22-24 mai (A. Reed, communication personelle). Leur arrivée à l'île Bylot est remarquée vers le 27 mai (Gauthier et Tardif 1991), leur présence étant généralement signalée dans la première semaine de juin dans les régions plus nordiques comme à l'île Ellesmere (Nettleship et Maher 1973), à l'île Cornwallis (Geale 1971) et au Groenland (Salomonsen *in* Lemieux 1959). Il peut ainsi exister au cours de certaines années un délai pouvant varier de quelques jours à près d'une semaine entre le départ de l'estuaire du Saint-Laurent et l'arrivée sur les aires de reproduction. Or un vol sans escale entre la halte printanière et l'île Bylot durerait normalement moins de 2 jours (Gauthier et al. 1992). Nos observations printanières suggèrent que le délai en question peut être attribuable au fait que la Grande Oie des neiges effectue un ou plusieurs arrêts au Nouveau-Québec au cours de ses migrations et que ce territoire pourrait alors être fréquenté pendant près de 5 jours. Comme nos observations ont été effectuées après les dates normales d'arrivée rapportées sur les aires de

nidification, il est possible que les volées d'oies observées soient principalement composées de sous-adultes. Ceux-ci ne nichant pas, ils pourraient se permettre d'arrêter en route vers les aires estivales de mue. Il est aussi possible que la période et la durée d'utilisation de ce territoire par la Grande Oie des neiges puisse varier annuellement selon les conditions météorologiques rencontrées. En effet, lors d'un inventaire de caribou subséquent, réalisé du 27 mai au 2 juin 1991 entre le 57° et le 62° nord (M.E.F., données non publiées), aucune Oie des neiges n'a été observée (D. Fiset, M.E.F., communication personelle).

Nos données recueillies à l'automne sont plus fragmentaires et permettent difficilement d'évaluer la durée de la halte effectuée à ce moment, de même que l'ampleur du territoire fréquenté. Néanmoins, les densités d'oies observées au cours de cette saison étaient jusqu'à 30 fois plus élevées qu'au printemps, laissant croire que la halte migratoire automnale des oies au Nouveau-Québec est encore importante pour une bonne partie de la population. La migration automnale s'échelonne sur une période beaucoup plus longue qu'au printemps; les oies quittent les aires de reproduction à la fin août (Lemieux 1959; J.-F. Giroux et G. Gauthier, observation personelle) et n'arrivent en grands nombres le long du Saint-Laurent qu'au début du mois d'octobre (Maisonneuve et Bédard 1992). Selon une étude réalisée sur la Petite Oie des neiges (*Chen caerulescens caerulescens*) nichant plus au sud (Wypkema et Ankney 1979), les jeunes oies n'ont pas le temps d'accumuler de réserves durant l'été en raison de leur croissance rapide. Une halte au Nouveau-Québec permettrait ainsi aux jeunes oiseaux d'accumuler les réserves nécessaires pour accomplir le reste de leur migration.

Bien que non supportées par des données de contenus stomacaux et d'études de bilan comportemental, nos observations sur le terrain indiquent que l'Oie des neiges consommerait une quantité importante de fruits lors de ses arrêts au Nouveau-Québec, et ce tant au printemps qu'à l'automne. Les fruits de certaines espèces, telles *Vaccinium vitis-idaea* L. et *Empetrum nigrum* L., sont mûrs au début de l'automne, mais persistent tout l'hiver sur la plante et certains sont même meilleurs au goûts à la fonte des neiges (Porsild 1973). Une consommation importante de fruits a aussi été notée pendant la période pré-reproductrice chez des Bernaches du Canada (*Branta canadensis*) et des Oies rieuses (*Anser albifrons frontalis*) nichant dans les régions nordiques (Reed et al. 1990; Budeau et al. 1991). Ces fruits présentent un contenu lipidique élevé, tant à la fin de l'été (Sedinger et Raveling 1984) qu'au printemps suivant (Brown 1954; Budeau et al. 1991). Ils représentent ainsi une source d'énergie qu'il ne faut pas sous-estimer.

Lors de nos inventaires d'automne, les pourcentages d'individus en phase de coloration bleue variaient de 1,1% à 3,1%. Ces proportions sont supérieures à celles qui sont observées sur les aires de reproduction de la Grande Oie des neiges aux îles Bylot et Baffin (de 0,09% à 0,75%; Reed et al. 1992), de même qu'à celle qui prévaut parmi les oiseaux qui effectuent une halte dans l'estuaire du Saint-Laurent (0,7%; A. Reed, données non publiées). Comme la proportion d'individus en phase de coloration bleue est beaucoup plus importante dans les colonies de Petites Oies des neiges situées au nord du Nouveau-Québec sur l'île Baffin (41% à 81%; Kerbes 1975), il est raisonnable de croire que celles-ci sont susceptibles de contribuer quelque peu aux effectifs observés au Nouveau-Québec.

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Relative Activity and Occurrence of Bats in Southwestern Ontario as Determined by Monitoring with Bat Detectors

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Hickey, M. Brian C., and Alison L. Neilson. 1995. Activity and occurrence of bats in southwestern Ontario as determined by monitoring with bat detectors. Canadian Field-Naturalist 109(4): 413–417.

Activity and occurrence of bats was studied in southwestern Ontario using bat detectors on 10 nights between 10 June and 10 July 1991. Four species, Big Brown Bat, *Eptesicus fuscus,* Red Bat, *Lasiurus borealis*, Hoary Bat, *L. cinereus,* and small brown bats, *Myotis* spp. were detected during the survey. *Lasiurus cinereus* was the most commonly encountered species and bat activity was markedly different from that depicted by mist net captures or museum records.

Key Words: Red Bat, *Lasiurus borealis*, Hoary Bat, *Lasiurus cinereus*, Big Brown Bat, *Eptesicus fuscus,* little brown bats, *Myotis* spp., activity, Hamilton-Wentworth Region, Ontario, occurrence.

There is a paucity of data concerning the occurrence and relative activity of bats in southwestern Ontario. Most of the available data comes from museum records reflecting accidental encounters and captures in mist nets or harp traps (van Zyll de Jong 1985). These types of observations can be misleading because bats that are common but adept at avoiding mist nets or traps may appear rare or go undetected (Fenton et al. 1987). Bat detectors allow biologists to monitor the ultrasonic echolocation pulses of bats and make it possible to survey and identify many species by their echolocation calls (e.g., Fenton and Bell 1981; Fenton et al. 1983). In some cases, monitoring echolocation calls provides a more accurate picture of bat abundance and species diversity than captures (e.g., Fenton et al. 1987).

Of the eight species of bats occurring in Ontario, only three species from the Hamilton-Wentworth Region (*Myotis lucifugus*, *Eptesicus fuscus*, and *Lasiurus borealis*) are represented in the collections of the Royal Ontario Museum. There are no specimens of *Lasiurus borealis* or *Lasiurus cinereus* from Hamilton-Wentworth in the collections of the Canadian Museum of Nature even though both lasiurines are common at other sites in Southern Ontario (e.g., Hickey and Fenton 1990; Furlonger et al. 1987).

The purpose of this study was to use bat detectors to assess the occurrence and relative activity of bats in southwestern Ontario. We also used this data to determine whether there were nonrandom associations between species and the habitat chacteristics.

Materials and Methods

We conducted our sampling between sunset and 0100 hours on 10 nights between 10 June and 10 July 1991. On each night, we recorded bat activity at five sites (Figure 1). We did not conduct surveys during rain since bat activity is depressed during these conditions (personal observations). At each site we monitored bat activity using a QMC mini bat detector (Ultrasound Advice, 23 Aberdeen Road, London, N5 2UG, England) for 5 minutes each at 20, 30, and 40 kHz (total = 15 min), and recorded the number of passes and buzzes. We defined a bat pass as a continuous train of echolocation pulses detectable on the bat detector and did not attempt to distinguish individual bats. Thus, our data represent levels of bat activity rather than numbers of individuals.

Feeding buzzes are echolocation pulses produced at a rapid rate by a bat as it attempts to capture airborne prey (Griffin 1958). We recorded feeding buzzes and bat passes to distinguish foraging bats from commuting bats. We used the key provided by Fenton et al. (1983) to identify the calls and could distinguish the calls of *Lasiurus borealis*, *Lasiurus cinereus*, *Lasionycteris noctivagans*, *Eptesicus fuscus*, and *Myotis* spp. The three species of *Myotis* that might occur in the area (*M. lucifugus*, *M. leibii*, and *M. septentrionalis*) could not easily be distinguished using this procedure. Consequently, we pooled all *Myotis* spp. Data on the echolocation calls of *Pipistrellus subflavus* have recently been published by MacDonald et al. (1994) but were not available when we conducted this survey.

The habitat in much of the region is dominated by urban or agricultural development with small areas of natural or second growth habitat scattered throughout. Most of the sites we sampled were dominated by a mixture of habitats. We divided habitat type into six categories: (1) around street lights, (2) near escarpment, (3) river or creek bank, (4) marsh or pond, (5) forest and (6) other (sites lacking these

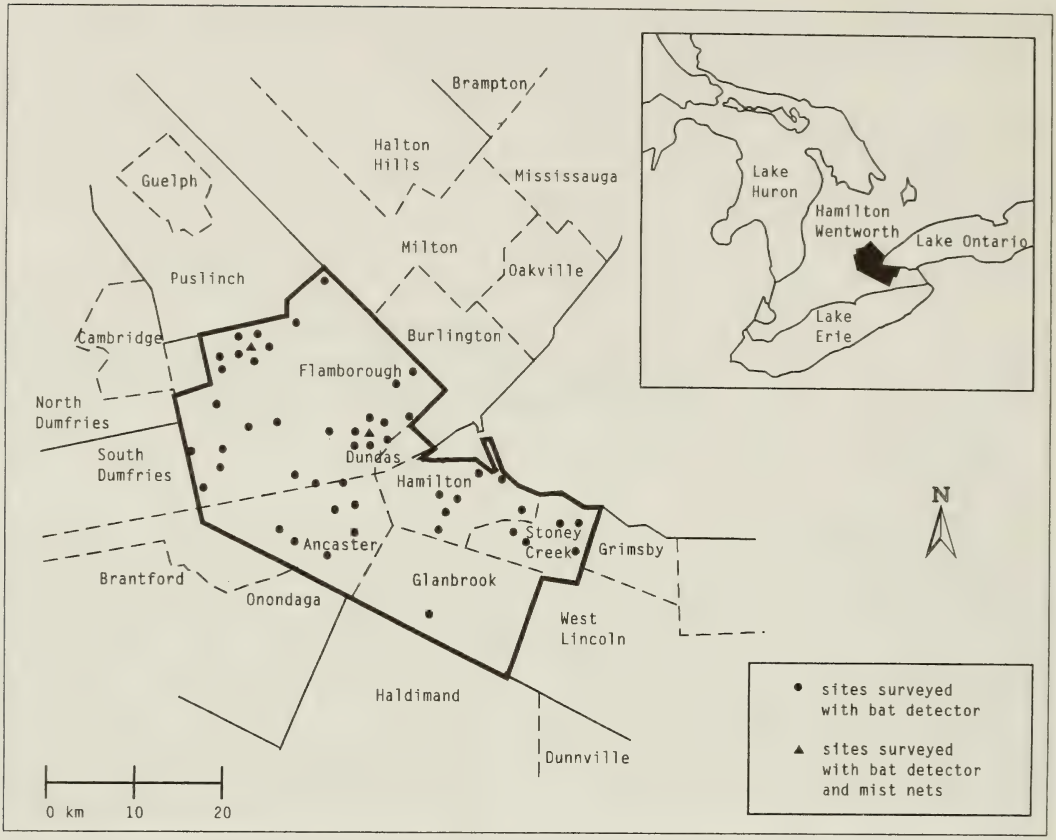

FIGURE 1. Map of the Hamilton-Wentworth Region showing the distribution of sampling locations and the two sites where mist nets were set. The locations of the sampling points are approximate and some were moved slightly to improve clarity.

features or composed of small amounts of several habitat types).

To supplement our bat detector data we set mist nets on two nights: at Valens Conservation Area (19 June 1991, 3 nets, 6 net-hours) and at Spencer Gorge Conservation Area (07 July 1991, 1 net, 1.5 net-hours)[Figure 1]. At Valens we set one net along a boardwalk over a marsh and two nets (one on top of the other) across a dirt road through forest. At Spencer Gorge we set one net across a dirt road which ran parallel to the gorge.

Results

At least four species of bats were identified with bat detectors (Table 1). *Lasiurus cinereus* was the most common species; it was detected in 15 out of 50 sampling periods. *Eptesicus fuscus* and *Myotis* spp. were also fairly common (8 and 9 samples respectively) and *Lasiurus borealis* was found in only two samples (Table 1). Bats occurred in all the habitats that we sampled except forest (Table 2). We used χ^2 tests to compare the frequency of activity by each species among habitat types, excluding *L. borealis* due to small sample size. To ensure each cell of the contingency table included at least 5% of the observations, we pooled some habitat categories ("Forest" + "Other" for *L. cinereus*; "River" + "Marsh/Pond" and "Forest" + "Other" for *E. fuscus*; "Forest" + "Other" + "Escarpment" for *Myotis* spp). The frequency of activity by *L. cinereus* and *E. fuscus* in different habitat types did not differ from that expected based on the availability of those habitats (*L. cinereus*: χ^2 = 1.93, $p > 0.75$; *E. fuscus*: χ^2 = 3.43, $p > 0.25$). *Myotis* spp. were not active in habitats in proportion to the availability of the habitats (χ^2 = 10.89, $p < 0.025$). We used the method described in Zar (1974) to determine which cell(s) of the contingency table contributed to the difference and found that the combined category "Forest"+"Other"+"Escarpment" explained the significant difference. *Myotis* spp. were less active in the combined forest+other+escarpment habitat cate-

TABLE 1. Relative activity of four bat species in southwestern Ontario between 10 June and 10 July 1991 as determined by bat detectors.

Scientific name (Common name)	Number of samples in which bat was detected*	Mean number of passes (Mean ± SD)	Mean number of buzzes Mean ± SD
Lasiurus cinereus (Hoary Bat)	15	7.6 ± 7.3	1.2 ± 2.1
Lasiurus borealis (Red Bat)	2	4.0 ± 4.2	0
Eptesicus fuscus (Big Brown Bat)	8	3.8 ± 6.2	0.1 ± 0.4
Myotis spp.	9†	6.7 ± 9.4	0

*N = 50 5-minute samples for each species.
†Probably *Myotis lucifugus* but different *Myotis* species are difficult to distinguish with bat detectors (see text).

gory than expected based on the availability of these habitats. The activity of *Myotis* spp. did not differ from that expected based on habitat availability for the other habitat types (Lights, River, Marsh/Pond; $\chi^2 = 2.0$, $p > 0.50$).

Although bat activity was evenly distributed among habitats (except for *Myotis* spp.) feeding buzzes were detected only at sites with lights or water, and only *Lasiurus cinereus* and *Eptesicus fuscus* produced feeding buzzes during our survey (Table 1).

In a total of 7.5 net-hours we captured a single male *Myotis lucifugus* at Valens Conservation area.

Discussion

Of the eight species of bats occurring in Ontario (Van Zyll de Jong 1985) four were detected during this study. *Lasiurus cinereus* was the most active species whether we used the number of samples in which it was detected or the average number of passes per sample period at locations where it was detected (Table 1). The relatively high activity of *Lasiurus cinereus* is particularly interesting and contrasts with the previous data obtained in Southwestern Ontario (Furlonger et al. 1987). Furlonger et al. (1987) found *L. cinereus* to be common (occurring in 55% of permanent sample locations) but *Eptesicus fuscus* was the most active species being detected in 89% of permanent sample locations. Furlonger et al. (1987) suggested that roost availability may play an important role in determining the abundance of *E. fuscus*. Lack of roost sites is unlikely to explain the lower relative abundance of *E. fuscus* in our survey since most of our sample locations were within 1 km of urban areas or rural towns which should have provided abundant roost sites.

Our data provide a much different impression of the bats of Hamilton-Wentworth than that based on museum records. There are no records of *Lasiurus cinereus* from Hamilton-Wentworth in either the Canadian Museum of Nature (Ottawa) or the Royal Ontario Museum (Toronto), even though it was the most active species in our survey. This underscores our lack of information about the occurrence and relative activity of Ontario bats, as well as the difficulty of drawing conclusions about local bat communities from distribution maps based on collection records or mist netting surveys (also see Fenton et al. 1987).

Bats were detected in all the habitats we sampled

TABLE 2. Relative activity of four bat species by habitat type in southwestern Ontario between 10 June and 10 July 1991. The number of times each type of habitat feature was sampled is given in brackets. Some locations contained more that one habitat feature, therefore, the sum of the numbers in brackets is >50 (i.e., the total number of samples). Values are the number of samples in which each species was detected.

	Habitat Feature					
	Lights (21)	Escarpment (12)	River (7)	Forest (6)	Marsh/Pond (11)	Other (4)
Lasiurus cinereus	7	3	1	0	5	2
Lasiurus borealis	1	0	1	0	0	0
Eptesicus fuscus	4	4	1	0	0	3
Myotis	3	1	3	0	3	0

except forest. There were no significant associations between activity and habitat types for any species except *Myotis* spp. which was more active near water or street lights but avoided other habitat types (i.e., "other", "forest" and "escarpment").

Our results concur with those of Furlonger et al. (1987) who found that none of the species they detected were restricted to a single type of habitat but were often associated with habitats where large concentrations of insects are common (e.g., lights and water). Habitat in our study area is highly fragmented making it difficult to detect associations between particular species and habitats but our results are consistent with several other studies indicating that most insectivorous bats are opportunists, foraging wherever there are large numbers of insects (Hickey and Fenton 1990; Fenton and Morris 1976; Bell 1980).

All of the *Myotis* we detected were probably *M. lucifugus* since this is the most common *Myotis* species in Ontario (unpublished observations). Also, *M. septentrionalis* and *M. leibii* have calls that are less intense than those of *M. lucifugus* and are therefore difficult to detect with bat detectors. In addition, we captured a single *M. lucifugus* during the two nights that we set mist nets.

The calls of *Pipistrellus subflavus* had not been described at the time of our study, therefore, we could not distinguish them in our survey. *Pipistrellus subflavus* produces echolocation calls which typically have two strong harmonics with energy between 35 and 19 kHz and 70 and 38 kHz respectively (MacDonald et al. 1994). They can be distinguished from other species by monitoring simultaneously with two detectors tuned to 20 and 40 kHz respectively (MacDonald et al. 1994). At these frequencies the calls of *P. subflavus* are audible as tonal signals that are distinctively different from those of either *L. cinereus*, *L. borealis* or *Myotis* spp. (MacDonald et al. 1994). All of the calls we detected at 20 or 40 kHz could be unambiguously assigned to either *L. borealis*, *L. cinereus*, or *Myotis*. Therefore, it is unlikely that *Pipistrellus subflavus* was present during our survey even though we were not specifically monitoring it.

We did not detect the presence of *Lasionycteris noctivagans* in our survey. This species has an echolocation call that is conspicuous on a bat detector (Fenton et al. 1983) and therefore we concluded it was not present during this study.

There are several limitations involved with the use of bat detectors for identifying bats. Thomas et al. (1987) have cautioned that since little is known about intraspecific variation in echolocation calls, species identifications based on bat detector outputs alone should be made carefully. Brigham et al. (1989) found significant inter-individual variation in echolocation calls of *Lasiurus borealis* and *Eptesicus fuscus*, and for some of the parameters that they measured, there was overlap between the two species. However, despite these cautions, most species (i.e., except *Myotis* spp.) in our study area emit calls that produce bat detector outputs which are distinctive and easily separated by experienced observers.

Some of the limitations of using a bat detector to identify species can be overcome by using a bat detector model that allows the signal to be fed into a period (Zero crossing) meter and oscilloscope (Simmons et al. 1979). This produces a visual image of the frequency pattern over time (sonogram) and can be used to distinguish *Myotis* species from each other.

Although *L. cinereus* was the most commonly detected species in our survey area, relative activity data must be compared with caution because the intensity of echolocation calls vary among species. Some species such as *L. cinereus* have high intensity calls that can be detected at much greater distances than those of *Myotis* spp.

Despite the difficulties discussed above, in areas where only a few species occur (e.g., eight species in Ontario), using bat detectors to monitor bat activity and identify species provides a more accurate impression of local bat populations than relying on mist netting or museum specimens.

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The Diet of Bald Eagles, *Haliaeetus leucocephalus*, Wintering in the Lower Great Lakes Basin, 1987-1995

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Observations of wintering Bald Eagles (*Haliaeetus leucocephalus*) from the lower Great Lakes basin feeding on identifiable food items provide an indication of winter diet for this population. Overall, 47% of 339 feeding observations were on carcasses of White-tailed Deer ((*Odocoileus virginianus*), 23% on fish, 11% on other mammal species, 10% on offal and human garbage, and 9% on birds. Only 35% of food items were of aquatic origin. Diet composition varied significantly by region, and eagle age. Garbage and offal formed 39% of feeding observations for immatures, but only 17% for adult eagles. Two-thirds of our observations were in the upper St. Lawrence River, where deer carcasses on the ice accounted for 62% of feeding records. Contaminant exposure could be relatively low for wintering eagles feeding on prey of terrestrial origin compared to those feeding on aquatic mammals, ducks, gulls and fish.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, diet, feeding, pellets, Ontario, Great Lakes.

The Bald Eagle (*Haliaeetus leucocephalus*) is a top predator and scavenger in aquatic and terrestrial food webs in the Great Lakes basin (Bortolotti 1987; Bowerman 1993). During the 1950s-1970s, breeding populations in the Great Lakes were severely depleted, or even extirpated locally, especially along the shorelines of the large lakes, due mainly to eggshell thinning, embryotoxicity and other effects of organochlorine (OC) contaminants (Postupalsky 1973; Sprunt et al. 1973; Weekes 1974, 1975; Grier 1982; Wiemeyer et al. 1984, 1993; Nisbet 1989; Bowerman 1993; Bowerman et al. 1994a,b,c). Accordingly, the Bald Eagle was added to the Ontario Endangered Species List in 1973. Since the mid-late 1970s (when most persistent OCs were banned and withdrawn from use) breeding numbers of Bald Eagles have increased steadily in the Great Lakes basin, although many former breeding territories in Ontario remain vacant (McKeating 1985; Bortolotti 1987; Kozie and Anderson 1991; Best et al. 1994; Hunter and Baird 1995). Corresponding increases in wintering numbers have also been noted, particularly around Lake Erie and in the upper St. Lawrence River (Tiner 1994; P. Hunter, Ontario Ministry of Natural Resources, personal communication).

During the past 30 years a considerable amount of eco-toxicological research has been conducted on eagles during the breeding season, particularly in the American parts of the Great Lakes basin (Postupalsky 1973; Grier 1982; Bowerman et al. 1990, 1994a,b,c; Bowerman 1993). The Bald Eagle is currently being proposed by government wildlife agencies in Canada and the United States as a basin-wide indicator of Great Lakes ecosystem health. The diet of nestling Bald Eagles has been reasonably well studied in the Great Lakes basin (Kozie 1986; Bowerman 1991, 1993; Kozie and Anderson 1991). Some immature Bald Eagles raised in Great Lakes nests move down the Mississippi flyway during their first 1-2 years of life, but once they reach sexual maturity, by about 4 years of age, they are relatively sedentary, and few adults move outside the Great Lakes basin (Bowerman 1991, 1993; Grubb et al. 1994; M. Shieldcastle, Ohio Department of Natural Resources, personal communication). Contaminants accumulated from food consumed during the winter months and early spring may be critical for Bald Eagles breeding in the Great Lakes, as some of these lipophilic compounds may be deposited in eggs laid from March onwards, particularly in times of food stress when females would draw upon stored lipid reserves to form eggs.

Thus, in order to understand better spatial and temporal patterns of OC contaminants and their effects in Great Lakes Bald Eagles, we need to know something about the diet outside the breeding period. In this paper we present the first reasonably extensive published account of the diet of Bald Eagles wintering in the lower Great Lakes basin.

Study Area and Methods

Observations were made of wintering Bald Eagles hunting or feeding on prey at various locations in the lower Great Lakes basin, from Manitoulin Island south to Lake Erie's north shore, and eastward to the St. Lawrence River (Figure 1). The observations were clustered in four general regions: the upper reaches of the St. Lawrence River (Ontario and New York); Lake Ontario shorelines; Lake Erie shorelines; and the Kawartha Lakes and Lake Huron

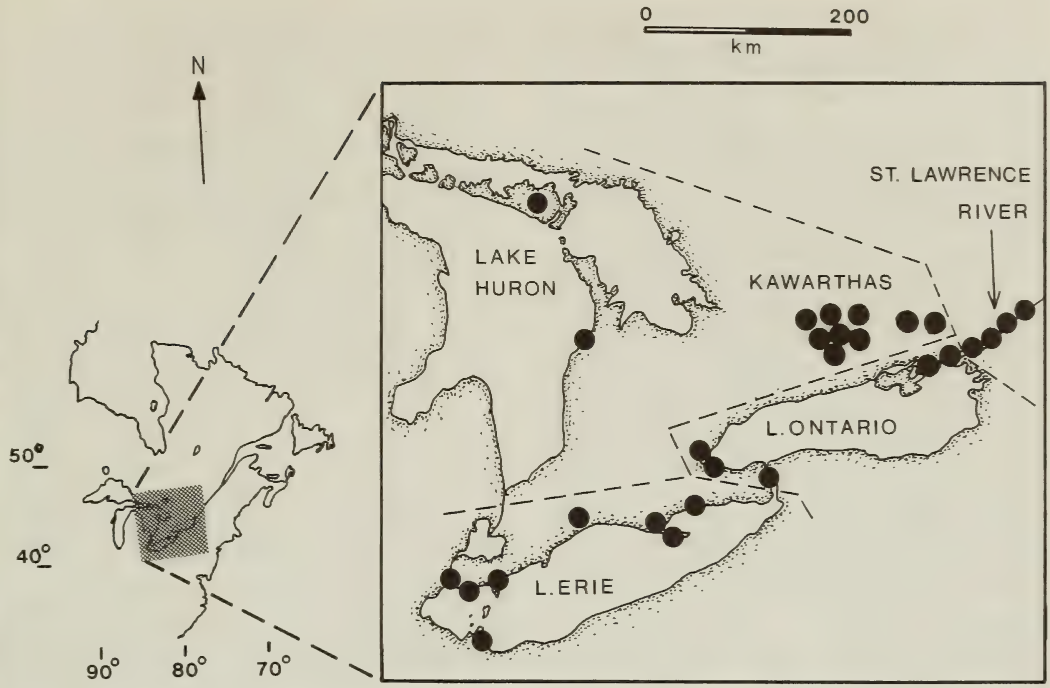

FIGURE 1. Location of areas where Bald Eagles were observed feeding during winter in the lower Great Lakes, 1987-1995, and the boundaries of areas referred to in text.

shorelines (Figure 1). We used records from 1987 to March 1995. Most inland lakes in the lower Great Lakes basin are usually completely frozen during much of the winter (November to March inclusive), and shorelines and wetlands around all the main Great Lakes were usually frozen between December and March. Some areas of open water remain throughout the winter on stretches of faster-flowing rivers (including the St. Lawrence), at warm-water discharges from power generating stations, and at urban effluent outfalls.

Observations were collated from a wide variety of sources, including our own field records. Requests for information were placed in newsletters of local naturalists groups, as well as at local offices of the Ontario Ministry of Natural Resources (OMNR). Active ornithologists were also contacted individually for their records. We made no attempt to select particular areas, but the time period was restricted to winter months. The following information was requested: type of food item the eagle was feeding on or clearly chasing/hunting (i.e. deer/mammal, waterfowl, gull, fish); the habitat in which the eagle was foraging or feeding (ice edge, river, woodlot); date and general location of the observation; age of the eagle (immature or adult plumage); and the location of any roost-site (so that regurgitated pellets could be collected later).

Feeding observations were collated from the period between late October and early April (range of observation dates were 2 November - 6 April). In the vicinity of breeding territories (e.g., along Lake Erie shorelines) late winter observations were terminated after early March, as eggs were normally laid there in March, up to a month earlier than further north in Ontario (Peck and James 1983; P. Hunter, OMNR, personal communication).

We considered a feeding record to be an individual eagle seen with an identifiable food item on a given day. Thus, a single eagle seen feeding on two separate days on the same item was recorded as two cases of feeding on that particular food type, whereas the same individual eagle at a deer carcass in the morning and again in the afternoon constituted a single feeding record. Many of the prey identifications were made with the aid of telescopes. Food items were identified to the highest taxon possible. In 24 cases an observer recorded an eagle feeding on food which was not identifiable. These cases were excluded from this account. Observations of foraging eagles were also considered if the observer was confident that the bird was actively pursuing/hunting a given type of food/prey. For the purposes of assigning prey to aquatic or terrestrial origins, gulls and waterfowl other than Canada Geese, *Branta canadensis*, were considered aquatic species. In

southern Ontario Canada Geese feed mostly in fields or grassy areas, parks etc. Aquatic mammals were Muskrat, *Ondatra zibethica*, and River Otter, *Lutra canadensis*. All other species and items were regarded as terrestrial.

In nine cases regurgitated pellets and reasonably fresh-looking prey remains (i.e., excluding old bones, skin and feathers which likely derived from the previous breeding season) were collected from beneath roost trees, and these remains of food items were identified using a Canadian Wildlife Service reference collection in conjunction with our own knowledge of local wildlife species and standard mammal and bird field guides. The occurrence of a food type in a pellet was taken as one case of an eagle feeding on that item; i.e., equivalent to a direct feeding observation. The age of eagles was scored as either adult (predominantly white head and tail) or immature. Statistical methods used follow those presented by Sokal and Rohlf (1981). The term significant is used in its statistical sense only, significance being accepted at the $P = 0.05$ level.

Results

Among the 339 occurrences of Bald Eagles feeding on identified food items during the winters of 1987-1995 around the lower Great Lakes basin, 47% involved White-tailed Deer (*Odocoileus virginianus*), 23% fish, 11% other mammal species, 10% offal or human garbage, and 9% birds (Table 1). Identified species and food types consumed are presented in Appendix 1. Overall, aquatic birds (waterfowl and some gulls) comprised 89% of the bird food items which could be identified, and aquatic mammals already mentioned made up 68%. For the entire region, in 324 cases where food could be identified as aquatic or terrestrial in origin, 114 cases (35.2%) involved aquatic animals (fish = 65; aquatic mammals = 25; waterbirds = 24).

There was some marked regional variation in prey items consumed (Table 1; Figure 2). This spatial variation was significant when fish, bird and mammal food categories were compared among the four areas ($G_6 = 47.0$, $P < 0.0001$). Notable regional variations in food consumed, at least when expressed on a percentage basis, were as follows: Lake Erie - a relatively low incidence of fish (3%) but high incidence of mammals other than deer (46%, comprising Muskrats and lagomorphs); large numbers of birds (40%) taken along Lake Ontario shorelines; apparently few deer (9%) were fed upon inland in the Kawarthas area. We knew of only five records of Bald Eagles scavenging deer carcasses in the Kawartha Lakes area, at Petroglyphs Provincial Park where up to 1800 White-tailed Deer winter. However, 9-12 Bald Eagles regularly wintered there, feeding on remains of deer killed by Wolves (*Canis lupus*), and up to seven eagles have been seen at one time feeding on a deer carcass there (Tiner 1994). Since no firm feeding records were available from Tiner's article, we were unable to include these as feeding observations. Deer carcasses provided almost 2/3 of the feeding observations in the upper St. Lawrence River. The only location at which eagles were recorded feeding on garbage or offal was in the Kawartha Lakes, involving regular scavenging at a relatively undisturbed landfill site, and at piles of cattle or deer offal placed out on the ice for birds like eagles.

For the five broad categories of food consumed (given in Table 1), there was significant variation according to eagle age class (based on 86 adult cases, and 61 immatures, $G_3 = 13.7$, $P < 0.01$; Table 2). The most notable age differences for the entire region occurred for garbage/offal, as 39% of immature feeding observations were in this category, compared with only 17% for adults. Along Lake Erie's shorelines mammals other than deer (mainly Muskrats and lagomorphs) were fed upon by adult eagles close to or on their breeding territories, but relatively few immature eagles wintered in these areas (probably because they were excluded by territorial adults). Among 19 cases of Bald Eagles observed actively hunting for identifiable prey types in the four regions, 11 (58%) involved birds pursuing waterfowl, either at the ice edge or over wetlands, 7 (37%) involved eagles fishing over water, and one was of an immature that plunged into deep snow, attempting to catch prey.

In most cases, the size of prey was difficult to record accurately. However, four Carp (*Cyprinus carpio*) were estimated to be 30 - 50 cm long. The larger fish had been left on the ice by anglers and

TABLE 1. The number (%) of occurrences of Bald Eagles feeding on different prey types in the lower Great Lakes, 1987-1995. Combined data from feeding observations and pellet contents.

Area	Fish	Bird	Deer	Other mammals	Garbage/ offal	Total
St. Lawrence River	59 (26.2)	14 (6.2)	139 (61.8)	13 (5.8)	0	225
L. Ontario	6 (30.0)	8 (40.0)	5 (25.0)	1 (5.0)	0	20
L. Erie	1 (2.7)	8 (21.6)	11 (29.7)	17 (46.0)	0	37
Kawarthas/Lake Huron	11 (19.3)	1 (1.8)	5 (8.8)	5 (8.8)	35 (61.4)	57
Total	77 (22.7)	31 (9.2)	160 (47.2)	36 (10.6)	35 (10.3)	339 (100)

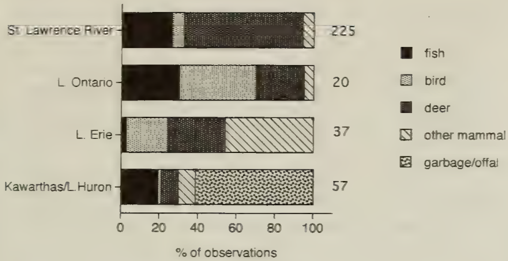

FIGURE 2. Regional variation in Bald Eagle winter diet composition in the lower Great Lakes, based on feeding observations and pellet analyses, 1987-1995. Number of observations is given for each region.

one was being eaten by a domestic or feral cat (*Felis catus*),when the eagle decided it wanted the fish (and maybe the cat too!). The source of deer carcasses was often difficult to establish from these single observations. Deer carcasses (and other animal offal) were sometimes put on the ice by local inhabitants who wanted to watch eagles and other scavengers feeding. In other cases deer had been shot by poachers and the remains were left on the ice or shoreline. Some deer were also known to have been forced out onto the ice by Coyotes (*Canis latrans*), where they were either killed, or sometimes fell through thin ice and perished, to be scavenged later.

Although no systematic records were maintained in the vicinity of Long Point, on Lake Erie, there were reliable reports of Bald Eagles regularly scavenging fish at commercial fishing trawlers immediately offshore (J. Robinson, Canadian Wildlife Service, personal communication). These same eagles also scavenged fish washed up along the Lake Erie shoreline. In Ohio's Sandusky Marshes, along the SW shore of Lake Erie, non-systematic observations during this period indicated that some fish and a few deer were consumed, but injured waterfowl were the main diet (M. Shieldcastle, Ohio Department of Natural Resources, personal communication).

Many observers reported interactions among Bald Eagles at animal carcasses, especially when a deer carcass was placed or staked out on the ice. The eagles usually displaced other scavengers at the carcass (such as Common Raven, *Corvus corax*, American Crow, *Corvus brachyrhynchos*, domestic cat and Coyote), but on one occasion in the St. Lawrence River, two Red Foxes, *Vulpes vulpes*, chased two Bald Eagles from a deer carcass. During the 1993-1994 winter a White-tailed Deer charged two adult Bald Eagles feeding at a deer carcass on the open ice in the St. Lawrence River. Black-capped Chickadees (*Parus atricapillus*), and Gray Jays (*Perisoreus canadensis*) were also recorded with eagles at carcasses, presumably either scavenging food themselves or mobbing the eagles.

Discussion

On the basis of birds observed feeding on identified food types, Bald Eagles wintering in the lower Great Lakes basin consumed a wide range of animals, as well as garbage and offal, presumably reflecting local availability of foods. There was significant regional and age-related variation in winter diet composition. Although the majority of feeding eagles were on ice or within 2 km of open water, aquatic animals comprised only 35% of feeding observations. This was due mainly to frequent scavenging of deer carcasses on ice or at the ice edge. In terms of biomass and energy, deer carcasses are considerably more important diet items than our observations suggest due to their large mass relative to other foods. However, we recognise that biases exist in the database, notably the greatly increased chance of observing a feeding eagle at a deer carcass on the ice, compared with other types of feeding cases.

These findings are important in respect of potential accumulation of organochlorine (OC) contaminants by wintering eagles. The two densest known concentrations of Bald Eagles wintering in southern Ontario — in the Kawartha Lakes, and in the upper St. Lawrence River [up to 40 birds in recent years (Tiner 1994)], appear to consume relatively little aquatic prey. Their heavy utilisation of deer carcasses and garbage/livestock and deer offal suggests relatively low exposure to OCs while wintering in these areas. Breeding eagles have not yet recolonized these areas however (Hunter and Baird 1995), and most of these wintering birds probably breed in northern Ontario and Quebec. One adult female wintering on the upper St. Lawrence River was followed by satellite telemetry to a summer location in northern Quebec in 1994 (P. Nye, New York State Department of Environmental Conservation, personal communication). However, the consumption of even a relatively small number of contaminated fish in the upper St. Lawrence River/eastern Lake Ontario area could potentially affect reproduction. Along the shores of Lake Ontario and Lake Erie,

TABLE 2. Number (%) of occurrences of feeding on different food items by wintering Bald Eagles in adult and immature plumages in the lower Great Lakes basin, 1987-1995.

Food type	Adult	Immature
Fish	24 (27.9)	20 (32.8)
Bird	9 (10.5)	4 (6.6)
Deer	18 (20.9)	11 (18.0)
other mammal	20 (23.3)	2 (3.3)
garbage / offal	15 (17.4)	24 (39.3)
Total	86	61

wintering eagles consume substantially more prey of aquatic origin (notably fish-eating birds) than in the two other areas. Due to biomagnification of OCs at successively higher trophic levels, this suggests greater exposure to these toxic compounds than for eagles wintering in the Kawartha Lakes area or the upper St. Lawrence River. However, reproductive success among Bald Eagles nesting along the north shore of Lake Erie appears to be sufficient now to at least maintain stable populations (Wiemeyer et al. 1984, 1993; McKeane and Weseloh 1993; Hunter and Baird 1995).

At present, we know little of the extent of movements among these wintering areas, either within or between seasons, and so it is difficult to predict whether contaminant exposure for individual Bald Eagles wintering in the lower Great Lakes, would in fact vary markedly by region. Elsewhere, the degree of wintering site tenacity in Bald Eagles is highly variable (G. Bortolotti, personal communication).

Food sources provided by humans (either actively or passively) are clearly very important for Bald Eagles wintering in this area. These observations undoubtedly underestimate the number of cases in which carcasses, fish or offal were placed on the ice for the purpose of viewing wildlife. Wintering Bald Eagles on lakes Superior and Michigan scavenge fish discarded by ice fishermen (Bowerman 1991; Bowerman and Giesy 1991), and also forage on gulls (Laridae), mergansers (*Mergus* spp.), Carp and Gizzard Shad (*Dorosoma cepedianum*) at warm-water discharges at some power generating stations. Concentrations of up to eight Bald Eagles similarly have been noted in the vicinity of the warm-water discharge from the Bruce nuclear power station on the Ontario side of southern Lake Huron (M. Parker, personal communication). In Michigan's Upper Peninsula, White-tailed Deer killed on highways are regularly taken by Bald Eagles throughout the year (W. Bowerman, personal communication). The anecdotal information from Petroglyphs Provincial Park (T. Tiner and G. Carpentier, personal communication) in the Kawartha Lakes area, suggests that sizable winter deer yards may be much more important for wintering eagles in the Great Lakes basin than is indicated by our collated observations. The greater use of landfill sites and offal/garbage by immatures, compared to adults, suggests that food availability may be an important limiting factor for Bald Eagles wintering in southern Ontario today. In Nova Scotia, Erskine (1968) noted that immature Bald Eagles were regularly supplanted by adults at feeding sites, and suspected that this led to concentrations of young birds away from adults. We believe this factor may explain the predominance of immature and sub-adult birds wintering in the Petroglyphs Park/Kawartha Lakes area, close to supplies of deer and garbage.

Although Lake Erie is a shallow, highly productive lake, these observations suggest that fish were scarce in the winter diet there. This impression may be misleading for two reasons. Unlike Lake Ontario, the shorelines are usually completely frozen out to at least 2-3 km during winter, so any eagle feeding on fish would rarely be seen from the coastal roads. Further, many of the dietary records were of food remains found beneath nests and nearby roosting trees in the late winter; small items such as fish scales and vertebrae would have been more easily overlooked than mammal fur, skin or bones, or bird feathers (see Mersmann et al. 1992).

Earlier this century, rabbits and hares (particularly those caught in traps by fur trappers) were regarded by Broley (1952) as an important source of food for Bald Eagles wintering in Ontario (one nest contained as many as 16 traps, some with Muskrat bones). Apart from these anecdotal observations, there are no previous dietary data for Bald Eagles wintering in the Great Lakes. The summer diet has been investigated in various parts of the basin, mostly in the USA (Kozie 1986; Bowerman 1991, 1993; Kozie and Anderson 1991). Those studies were based mostly on analyses of prey remains at nests. Fish, of a wide range of species, were the most frequent prey items (50-83%), followed by birds (mostly aquatic species) (up to 48%) and mammals (1-2%). Aquatic birds, notably gulls, were taken significantly more often at Great Lakes shoreline sites than further inland, reflecting their breeding distribution (Kozie and Anderson 1991; Bowerman 1993). However, it is difficult to compare these diet compositions with those of our wintering birds because analysis of Bald Eagle prey remains tends to overestimate avian and mammalian items and underestimate fish prey (Kozie 1986; Todd et al. 1982; Mersmann et al. 1992). At six nests in northern Michigan in 1990, direct observations of prey delivered to nests revealed a greater dependence on fish than when prey remains were used; fish were the main food (93%), followed by mammals (4%), birds (1%), and amphibians/reptiles (1-2%) (Bowerman 1993).

Thus, whether expressed in terms of frequency of occurrence or as biomass, fish, and sometimes aquatic birds such as gulls, are important in the diet of breeding Bald Eagles in the Great Lakes, whereas in winter, at least around the lower Great Lakes, deer carcasses appear to be the most important food item. This suggests that the summer diet could be more contaminated with OCs than that in the winter, and so it is possible that nestling Bald Eagles may be at greater risk from exposure to elevated levels of OCs than are adult Bald Eagles and their eggs.

In Maine, Bald Eagles wintering inland also appeared to rely heavily upon deer carcasses — winter-starved, or killed by trains — and carcasses of

domestic cows and beaver, as well as moose (*Alces alces*) and crippled waterfowl (Todd et al. 1982). Along the Platte Rivers in Nebraska, examination of wintering Bald Eagle pellet contents revealed mostly fish consumption when ice cover was less than 80%, but a shift to waterfowl and mammals when rivers were completely frozen (Lingle and Krapu 1986). Similarly in Missouri, Bald Eagles fed heavily on crippled waterfowl during normal winters, but switched to dead fish in winters when impoundments thawed (Griffin et al. 1982). In northern California and southern Oregon, wintering Bald Eagles fed entirely upon small terrestrial mammals and waterfowl, and some birds accumulated lethal doses of lead, primarily from hunter-crippled ducks (Frenzel and Anthony 1989). In southern Ontario, hunter-crippled ducks are also taken when available (an adult Bald Eagle which was diagnosed as having died from lead poisoning was recovered recently from the northeastern shores of Lake Ontario). The Ontario observations broadly match findings from winter diet studies in other areas, in that relatively little open water was present during winter in most areas away from Lake Ontario, and so waterfowl formed a relatively small part of the diet. In general, most of these studies illustrate the flexible and opportunistic foraging strategies of Bald Eagles at this stressful time of year.

There are biases associated with using direct observations of feeding eagles, as we have done. For example, birds feeding on highly visible and identifiable items such as larger mammals, birds or fish are more likely to be recorded than those feeding on prey such as small fish, passerine birds, or small mammals. Similarly, the use of regurgitated pellets will underestimate larger mammals or offal, since indigestible material such as large bones may not be consumed by the eagle (e.g., Frenzel and Anthony 1989). For these and other reasons, Mersmann et al. (1992) concluded that an accurate assessment of Bald Eagle diet requires the simultaneous use of different techniques. However, as we were unable to locate many in any communal roosts at which to collect pellets, and could not trap birds to examine regurgitates, direct feeding and hunting observations were the main measures available to us.

These observations from the lower Great Lakes basin support the conclusions of Gerrard and Bortolotti (1988), that "winter is the time when eagles search for and eat whatever food they can find", and so they "gather where prey is plentiful". White-tailed Deer appear to be a relatively important source of winter food here, but Bald Eagles concentrate at other reasonably predictable sources of food, such as open water areas and landfill sites.

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APPENDIX 1. List of prey taxa and categories utilised by wintering Bald Eagles in the lower Great Lakes, 1987-1995.

Fish
- Alewife (*Alosa pseudoharengus*)
- Carp (*Cyprinus carpio*)
- Yellow Perch (*Perca flavescens*)
- unidentified Centrarchidae
- unidentified fish

Birds
- Common Merganser (*Mergus serrator*)
- Canada Goose (*Branta canadensis*)
- unidentified dabbling duck
- unidentified diving duck
- Gull spp., probably Herring Gull (*Larus argentatus*) or Great Black-backed Gull (*Larus marinus*)
- Rock Dove (*Columba livia*)

Mammals
- White-tailed Deer (*Odocoileus virginianus*)
- Raccoon (*Procyon lotor*)
- Lagomorph spp. [probably Eastern Cottontail (*Sylvilagus floridanus*) or Snowshoe Hare (*Lepus americanus*)]
- Vole spp. (probably *Microtus pennsylvanicus*)
- River Otter (*Lutra canadensis*)
- Beaver (*Castor canadensis*)
- Muskrat (*Ondatra zibethica*)

Garbage/offal
- Heads of White-tailed Deer
- sides of beef
- miscellaneous garbage at landfill site
- discarded fish/offal

Phenology and Breeding Success of Feral Rock Doves, *Columba livia*, in Toronto, Ontario

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Ewins, Peter J., and Dawn R. Bazely. 1995. Phenology and breeding success of feral Rock Doves, *Columba livia*, in Toronto, Ontario. Canadian Field-Naturalist 109(4): 426–432.

At a colony site of feral Rock Doves (*Columba livia*) in Toronto, Ontario, breeding in 1991-1994 occurred in every month of the year. Numbers of active nests (ANs) and reproductive success peaked in winter (November - April: 47% nest success, mean 0.7 young fledged per AN), and were much lower in summer (May - October: 25% nest success, mean 0.3 young fledged per AN). Many previous studies have found the reverse seasonal effect. Super-abundant food, supplied in winter by humans, and regular human disturbance during the summer were the most likely factors causing these seasonal patterns.

Key Words: Feral Rock Dove, *Columba livia*, phenology, breeding success, winter, food, urban, Ontario.

The feral Rock Dove, *Columba livia*, the lineal descendent of wild Rock Doves via domestic pigeons, is today widely distributed in agricultural and urban habitats throughout North America and many other parts of the world (Goodwin 1970; Cramp 1985; Godfrey 1986; Armstrong 1987; Johnston 1992). These populations are derived from Old World dovecote pigeons which were first introduced into North America in the early 17th century by European settlers who established feral domestic stocks to augment food supplies (Schorger 1952; Goodwin 1970). Humans appear to have been domesticating feral Rock Doves at least 6500 years ago, in Iraq (Murton et al. 1972).

Many species of pigeons and doves (Columbidae) have protracted breeding seasons, often with multiple broods (up to eight in some cases) in a year (Cramp 1985; Perrins and Middleton 1985). Year-round breeding by feral Rock Doves has been well documented by studies in a number of countries, notably Finland (Häkkinen et al. 1973), Scotland (Lees 1946), England (Murton and Clarke 1968), and the U.S.A. (Townsend 1915; Dunmore and Davis 1963; Johnston 1992). In Europe, however, most pairs appear to stop breeding during late August and September, during the main moult period (Goodwin 1970). In North America, primary moult appears to be less synchronous than in European Rock Doves, and reduced breeding activity has been noted in the November - January period (Johnston 1992).

There have been few ecological studies of feral Rock Doves in Canada, despite the close proximity of this species and humans in many parts of the country, and its unusual position among birds (along with Red Crossbill *Loxia curvirostra* and White-winged Crossbill *L. leucoptera*) of breeding in the middle of the long, cold Canadian winters (Lumsden and Smith 1987; Smith and Lumsden 1987). The only detailed Canadian studies have been in Montreal, where foraging and social behaviour were investigated (Lévesque 1983; Lefebvre and Giraldeau 1984; Lefebvre 1985, 1986; Lévesque and McNeil 1985), and two studies of urban habitat preferences, in Vancouver (Weber 1972, 1975) and Toronto (Savard 1978; Savard and Falls 1981). Winter breeding of feral Rock Doves has been recorded in coastal British Columbia (Erskine 1976), Edmonton, Alberta (McGillivray 1988), southern Ontario (Peck and James 1983), Montreal, Quebec (Lévesque and McNeil 1985) and in the Atlantic provinces (Erskine 1976, 1992), but there appears to be no published systematic study of breeding phenology or success in Canada. An analysis of 137 nest record cards suggested that feral Rock Doves bred in Canada mostly between March and June (Erskine 1976), but seasonal biases in nest reporting were not taken into account.

In this paper we report the results of a three-year study of breeding at a colony of feral Rock Doves in central Toronto, southern Ontario, and examine various factors which may have influenced the seasonal pattern of breeding which we observed.

Study Area and Methods

The study colony was underneath a bridge supporting subway tracks above Indian Road, at Keele subway station, in central Toronto (43°40′N) (Figure 1). The doves nested on a broad concrete ledge and also on three metal covers over bright lights. These lights illuminated the road at night, but the area above them (i.e., where the birds nested) was dimly

FIGURE 1. Photograph of the Keele subway / Indian Road study colony, Toronto, 1995.

lit. All nests were about 4-5 m above ground level, and were inaccessible to mammalian predators. Each site was sheltered from direct precipitation, but the main ledge became wet during periods of thawing or in heavy rain storms. Doves roosted either at the nest sites, or on 4-inch diameter cast iron drain pipes suspended beneath the bridge. Indian Road is a relatively quiet street, with light vehicle and residential pedestrian traffic at all times of year. No other concentrations of feral Rock Dove nests were known within 1 km of the study colony, but scattered pairs nested under eaves and overhangs of older residences in the neighbourhood during the summer months (cf. Savard 1978).

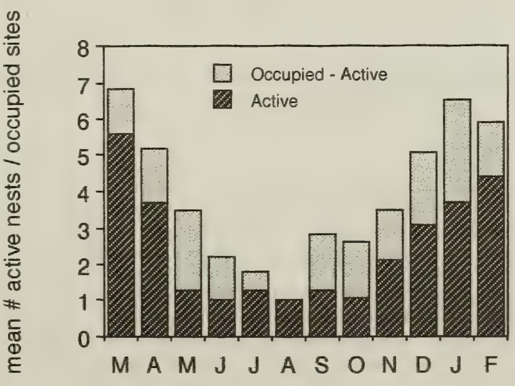

FIGURE 2. Monthly variation in the mean number of active and occupied feral Rock Dove nests (1991-1994 pooled data) at the study colony.

Observations were made on a regular basis at this colony for three years, between March 1991 and February 1994. On a monthly basis, up to 16 censuses were made of the number of occupied and active sites. Colony visits were made at various times of day between 0615 h and 1800 h local time. Following definitions now widely accepted for raptors (Postupalsky 1974; Steenhof 1987), an occupied site was taken to be a suitable-looking nest site at which there was fresh nest material, or at least one adult, or chick(s) visible. An active nest site was one in which breeding had definitely been attempted, as determined by either an adult observed in incubating posture for at least one minute, or some other evidence of breeding such as adult feeding young, broken or hatched eggshell, or unfledged chicks present. Thus, all active nests were scored as occupied sites. Clutch initiation dates were estimated by back-calculations, either from the date at which incubation was first noted [usually commences after laying of second egg, about two days after first egg laid (Johnston 1992)], or from estimated chick ages or fledging

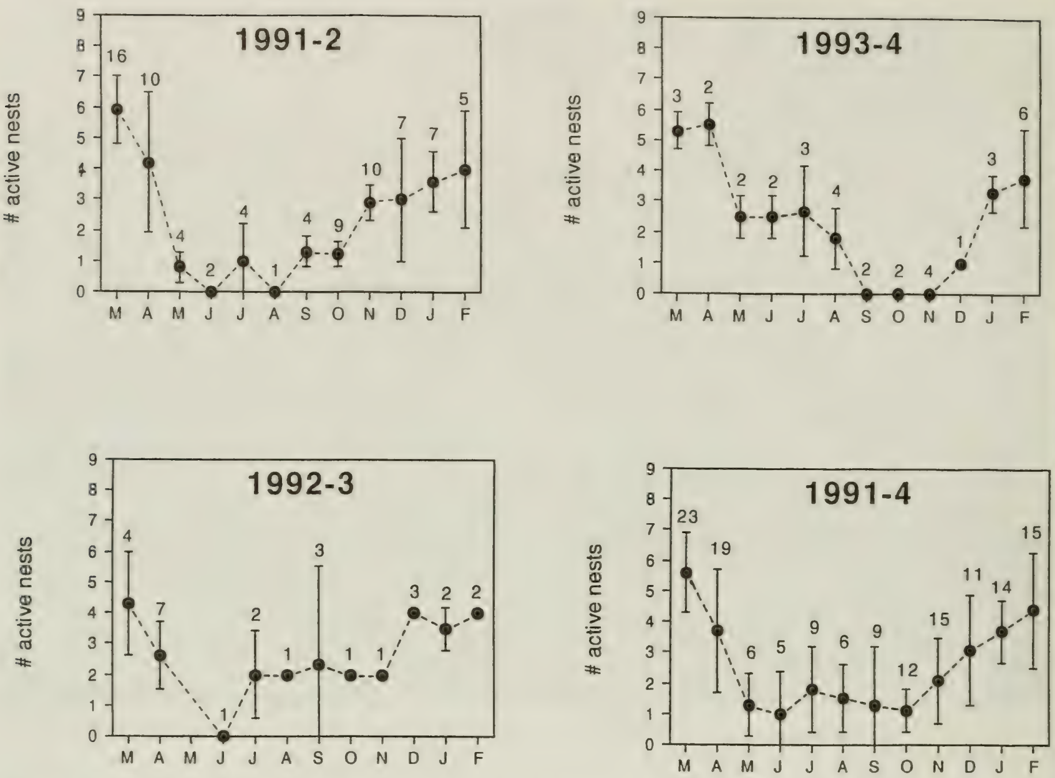

FIGURE 3. Mean (± 1 s.d.) numbers of active nests of feral Rock Doves at the study colony, 1991-1994. Sample size given for each month is the number of days on which a nest census was conducted.

dates [using an incubation period of 18.5 days (Johnston 1992) and a fledging period of 35-37 days (Cramp 1985)]. An active nest was scored as successful once it contained at least one chick thought to be capable of flight.

Fewer censuses were made during the summer months once the low number of occupied nests became apparent. Additional notes were kept of any human disturbance, supplementary feeding of feral Rock Doves in the immediate vicinity, or of potential egg predators. The majority of birds in this colony were of the grey ("wild-type") morph, and because none of these birds was banded or marked in any way we were unable to investigate movements of individuals or turnover rates of adults at specific sites. The area beneath each occupied nest was searched regularly for eggshells. Eggshells were rinsed in tap water to remove any lipid and albumen and stored at room temperature for 1-2 months. Six measurements of shell thickness were made for each of the failed, unhatched eggshells by sampling small (approximately 4mm x 6mm) pieces of shell with membranes attached from the equator region. Hatched eggshells were distinguished from unhatched ones by the separation of membranes and shell, which occurs during the hatching process.

Statistical methods follow those of Sokal and Rohlf (1981). The term significant is used in its statistical sense only, significance being accepted at the P = 0.05 level. For the purposes of this paper, we considered the months of November - April (inclusive) to be winter, and May - October to be summer (cf. Murton and Clarke 1968). In Toronto early May usually marks the start of above-ground growth for many trees and other plants.

Results

Temporal trends in nest numbers

There was a highly significant positive correlation between the number of occupied sites and the number of active nests ($r = 0.84$, $F_{1,113} = 282.2$, $P < 0.0001$; number of active nests = 0.71 x number of occupied sites + 0.039). The seasonal trend in numbers of nests was similar for active nests and for occupied sites, with highest numbers from December to April inclusive, and lowest numbers between May and October (Figure 2). Subsequent analyses dealt only with active nests. This general

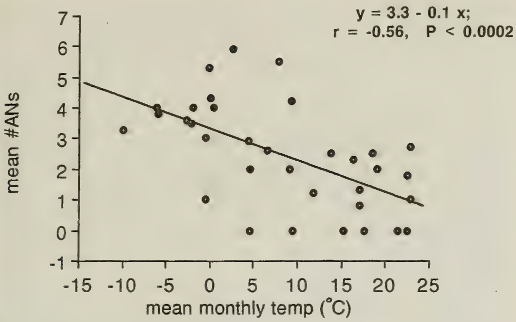

FIGURE 4. Relationship between mean numbers of active nests and mean air temperatures for 35 months during the study period. Linear regression line is shown.

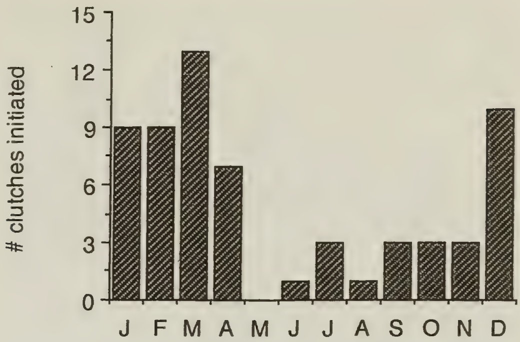

FIGURE 5. Monthly variation in estimated clutch initiation dates for feral Rock Doves at the study colony, 1991-1994.

seasonal pattern was consistent for active nests in each of the three study years, although there was some slight variability among years, particularly for the summer months when nest numbers were low (Figure 3). Peak numbers of active nests were usually noted in the late winter: eight in February and March in 1991, six in March 1992, and six in March and April of 1993. The highest sumer total was six in September 1992. Counts of fully-grown feral Rock Doves within sight of the colony (usually either feeding in the subway carpark, or perched on a nearby high roof) averaged significantly higher in the winter than during the summer (30.6 ± 13.7 vs. 3.5 ± 3.9 birds, $t_{18} = 4.7$, $P < 0.0002$).

There was a highly significant negative correlation between mean monthly numbers of active nests and mean monthly air temperature (°C) recorded in downtown Toronto (Environment Canada records, unpublished) ($r = -0.56$, $F_{1,33} = 17.2$, $P < 0.0002$) (Figure 4). January and February 1994 were the coldest months during the study (mean air temperatures – 10.0°C and – 6.0°C, respectively), but on average during these months there were 3-4 active nests (Figure 3). Mean monthly air temperatures in December to March of the previous two winters were in the – 3°C to + 3°C range (Environment Canada, unpublished meteorological records).

Reproduction

Overall rates of nest success in winter (47%) were almost double those in summer (25%), and mean numbers of young fledged per active nest were nearly three times higher (0.69 vs. 0.25 young per AN). Only two chicks were known to have fledged during the summer months in the three study years. Overall, 43% of active nest attempts were successful in fledging at least one young, and mean production for 44 nesting attempts was 0.61 fledglings per nest (Table 1).

Among 62 separate nesting attempts in the three study years for which the date of clutch initiation could be estimated (see Methods), 82.3% of these clutches were initiated in winter, whereas only 11 (17.7%) were initiated in the May - October summer period (Figure 5).

Eggshell thickness

Mean shell thickness for six eggs or broken shells found beneath nest ledges was 0.233 ± 0.010 mm (s.d.) (range 0.216 - 0.245 mm). We were unable to find any published values for eggshell thickness in feral Rock Doves to compare with our data. However, we have no evidence to suggest that thinning of eggshells, caused by organochlorine pesticide residues (usually DDT and its metabolites in many bird species), contributed to reproductive failures in this study.

Human activities

In each of the three study years, large quantities of stale bread, rolls, muffins, cakes, and other discarded food were put out by elderly citizens for the

TABLE 1. Reproductive outcome, by season, of feral Rock Dove nesting attempts at the study colony, 1991-1994. (AN = Active nests).

Season	Number of nesting attempts	Number (%) successful	Chicks fledged	
			Number	Mean number / AN
May - October	8	2 (25%)	2	0.25
November - April	36	17 (47%)	25	0.69
Total	44	19 (43%)	27	0.61

feral Rock Doves and other birds beneath this colony, almost daily from early November to late February. Up to 40 feral Rock Doves could be seen feeding on this rich food supply. There was always a surplus. Food was provided in this manner only rarely at other times of year, presumably because these people considered that the birds needed food only when temperatures fell to the freezing mark or below. Feral Rock Doves initially feed their young with cropmilk, and then with grain and seeds as the chicks grow (Johnston 1992), so this supply of food should, provided it contained sufficient lipid, proteins and essential elements, have enabled young to be raised successfully.

Severe human disturbance at the colony occurred only between mid-April and mid-October. Relatively few youngsters played outdoors locally at other times of year. On 14 April 1991, a youth was throwing stones and rocks deliberately at the feral Rock Doves and the street lights on which their nests were placed. In all years this six-month period coincided with the baseball season, and at times up to four youths practiced baseball under the subway tracks at the colony. This baseball activity heightened towards the end of the season in 1992 and 1993, when the Toronto Bluejays team went on to win the World Series in both years !

Discussion

Our results confirm that the feral Rock Dove is one of the few Canadian bird species which can breed at any time of year. At this colony in Toronto, breeding activity was more extensive and successful during winter than in summer. This was evident whether we considered numbers of active nests, occupied sites, clutches initiated, or mean numbers of full-grown birds within sight of the colony. Although winter breeding has been recorded previously in North American feral Rock Doves (e.g., Erskine 1976, 1992; Peck and James 1983; McGillivray 1988; Johnston 1992), there has been little indication until now of greater productivity or breeding activity in winter than in summer. In Kansas, most breeding activity occurred between February and September, and nesting attempts in winter were less successful than in summer (Johnston 1992).

Winter air temperatures (not adjusted for windchill factor) in Toronto regularly fell below 0°C, and in January and February overnight lows were often in the −10°C to −20°C range. Previous winter records of breeding, in Edmonton (53° 40′N), were in similar sheltered locations to our colony, in an unusually mild winter, with mean monthly temperatures of −5°C (and average monthly minima of −9°C) (McGillivray 1988). In Pennsylvania (at latitude 40° 48′N) fecund male and female feral Rock Doves were collected throughout one winter in which mean monthly air temperatures ranged from −2°C to −4°C , and minimum temperatures were −13°C to −19°C (Dunmore and Davis 1963). Winter nesting at higher latitude, in Finland (61°30′N), occurred in factory lofts where mean monthly air temperatures ranged between −5°C and +2°C (Häkkinen et al. 1973). We conclude that feral Rock Doves are capable of breeding successfully in sustained sub-zero air temperatures provided reasonably sheltered nest sites and adequate food supplies are available.

Detailed studies in Europe have found varying phenologies for feral Rock Dove colonies. In Finland, feral Rock Doves bred throughout the year, with peak nest numbers in an indoor colony between January and August, and no breeding in October and November (towards the end of the main moult period, apparently) (Häkkinen et al. 1973). Higher numbers of nests were also noted during the winter and spring than in summer and autumn during a study of wild Rock Doves in sea caves in Scotland (Lees 1946). Perhaps the most detailed studies of urban feral Rock Doves have been those by Ron Murton and colleagues in England. In Manchester docks, hatching success and numbers of active nests tended to be higher in spring and summer than in winter and over half the males in January – July had enlarged gonads (larger than 500 mm^3), compared to only 31-47% in August – December. In fact, although virtually all birds were capable of breeding, only about one third of this population actually produced eggs (Murton et al. 1972, 1974). Similar breeding phenology was found for a coastal population in Yorkshire (Murton and Clarke 1968).

The seasonal pattern in breeding activity which we detected was probably influenced by three main factors: food availability, human disturbance, and dispersal in summer. We did not have a marked population of birds, so we were unable to know whether birds moved to nearby residential areas to breed during the summer months. Our casual observations indicated that during the winter few, if any, feral Rock Doves bred at sites among the eaves and above the porches of the older houses nearby, whereas in summer individual pairs bred at such locations. Savard (1978) and Savard and Falls (1981) also noted pairs nesting in such situations in summer in older residential areas of Toronto. Many of these sites were relatively open and exposed to wind and drifting snow. We have no counts of these nests, due to the difficulty in censusing all the residential properties thoroughly. We also have no idea how far these feral Rock Doves may have moved between foraging areas and different breeding locations. Elsewhere in Toronto, as in other Canadian large towns and cities and in some rural areas, feral Rock Doves also nest commonly under road bridges (personal observation, A. J. Erskine personal communi-

cation). It is possible that at underpasses more distant from human food supplies, nesting numbers and success of doves may not be higher in winter than in summer.

We witnessed predation of active nests by American Crows (*Corvus brachyrhynchos*) on two occasions, but suspect that the main causes of nest failure were human disturbance/vandalism, and some flooding on the main nest ledge during periods of rapid ice melt (March mainly), or during summer thunderstorms. Our overall production figures are difficult to relate directly to other North American data, as these have usually been presented as the percent of eggs which gave rise to fledged young. Johnston (1992) found this ranged between 20 and 45%. Winter (November-January) breeding attempts in Finland fledged at least one young in 56% of 59 nests (Häkkinen et al. 1973), very similar to our figure of 47% for winter. In Manchester, England, Murton et al. (1972) recorded greater reproductive success in May – October (53-66% of eggs laid producing fledglings) than in winter (November – April, 37-52%), contrary to our lower productivity among summer nestings. Seasonal variation in food availability and physiological condition of the adults are likely explanations for these differences.

We suspect that the presence of a super-abundant supply of food during winter at this Toronto study colony, combined with relatively little serious human disturbance then and relatively sheltered conditions at most nest-sites, enabled feral Rock Doves to breed throughout the winter, despite mean monthly temperatures down to – 10°C. The significant negative correlation between nest numbers and mean monthly air temperature was likely confounded heavily by seasonality in the above factors, rather than being indicative of a real temperature-dependent effect on breeding condition of feral Rock Doves. Contrary to results in European studies, where fledging success in summer is often double that in winter, due mainly to food availability (Cramp 1985), we found that productivity in winter was almost twice that in summer — again probably due to super-abundant local food resources. In eastern Kansas, failure rates in winter months, of eggs and nestlings, averaged higher (by 7% and 13%, respectively) than the mean for the year, but in some years winter reproduction was more successful than that of the preceding summer (Johnston and Janiga 1995).

However, we do not know the extent to which birds which bred at this colony during the winter dispersed to breed during the summer too, perhaps in surrounding residential areas (or other locations further afield), or even where these birds spent the summer months. Some feral Rock Doves are capable of breeding when only 5-7 months old, but reproductive success is considerably lower than among older, more experienced birds (Johnston 1992; Johnston and Janiga 1995), and many young females lay only 1-egg clutches (Johnston and Johnson 1990). Another possible explanation for the reduced productivity we found in summer is that adult breeders vacated the colony when human disturbance intensified, and then young birds occupied these nests sites until the following winter. Further studies with marked birds and extensive surveys within a few kilometres of the colony would be needed to clarify this situation.

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Diet and Internal Anatomy of Male Sharp-tailed Grouse, *Tympanuchus phasianellus*, as Related to Age and Position on the Lek

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Heart weight, gizzard weight, and caeca length of male Sharp-tailed Grouse (*Tympanuchus phasianellus*) that occupied central territories on four leks near Fort Albany, Ontario, were significantly but not disproportionately larger compared to peripheral individuals (and yearlings). Thus, relative heart size did not explain higher levels of activity maintained by central males and adults on the lek. No advantage in digestive efficiency between the classes studied was found using digestive morphology as the criterion. Further, no differences were found between age and lek location in type and energy content of diet. Perhaps differences in body condition between the classes, as has been shown previously, can be related to differences in gastro-intestinal microflora.

Key Words: Sharp-tailed Grouse, *Tympanuchus phasianellus*, age, territorial position, spring foods, internal anatomy.

Male Sharp-tailed Grouse, *Tympanuchus phasianellus*, occupying central territories on leks are preferred by females as mates and expend more energy on lek attendance and territorial defense than individuals in peripheral territories (e.g., Kermott 1982). Furthermore, male sharptails in central territories are in better body condition than peripheral males, as are adults compared to yearlings (Tsuji et al. 1994). Body condition, or the ability to maintain body condition, in grouse appears to be related to mate choice (based on activity level) and may be related to individual differences in digestive tract morphology or energy content of diet. Relative heart size also may be of importance in relation to activity levels of individuals at the lek. Heart size in birds has been related to activity, with an increase in size being correlated with an increase in activity level (Hartman 1955). In the present study of lekking Sharp-tailed Grouse, we compare territorial position (important in mate choice) and age to variation in heart size, digestive morphology, and diet (type and energy content).

Methods

Study sites were in muskeg on the western shore of James Bay, near Fort Albany, Ontario (52°15′N; 81°35′W: see Hanson 1953 for a detailed habitat description). Forty-nine male Sharp-tailed Grouse were "harvested" by native Canadians from four separate leks during the 1992-1993 breeding seasons. Shape and feather wear of outer primaries were used to distinguish between yearlings and adults (Ammann 1944). Males were classified prior to collection as those possessing either central or peripheral territories (Tsuji et al. 1992).

Three morphological variables were measured on each specimen: body mass, fresh weight following collection; heart, following Hartman (1955); and gizzard, after removal of contents. All were measured to the nearest 0.1 gram on a triple-beam balance. A subset of 23 individuals from two leks was processed following Fenna and Boag (1974) to determine caeca lengths (to the nearest 0.5 cm) for each individual.

Data were analyzed using procedures contained in SAS (SAS Institute 1982). Morphological variables were transformed to natural logarithms, samples from central and peripheral males along with samples for adults and yearlings were found to be normally distributed (Sharpiro-Wilk's test: Shapiro and Wilk 1965). Variation in character means between central and peripheral males and between adults and juveniles were assessed by single-classification analysis-of-variance (ANOVA). For peripheral birds, data for heart and gizzard were subject to a Wilcoxon rank-sum test between adults and yearlings. Linear-regression analysis was used to examine the relationship between heart and body mass, gizzard and body mass, and caeca length and body mass among individuals.

Energy content of diet (i.e., gross energy, kJ/gram of dry matter) was assessed by drying gizzard contents at 60°C for three days, grinding and pulverizing the dried material, and then completely oxidizing approximately one gram of dry matter in an oxygen bomb calorimeter (Evans and Dietz 1974). Diet data were not normally distributed for the classes examined. Wilcoxon rank-sum tests between central and peripheral individuals, and between yearlings and adults were performed.

TABLE 1. Morphometric characters and ANOVAs between juvenile and adult males, and males occupying peripheral and central territories on leks, of Sharp-tailed Grouse.

	Heart weight, g			
	N	$\bar{X}$	SD	F[a]
Peripheral	26	11.1	1.0	8.83**
Central	19	12.0	0.9	
Adult	23	12.0	0.9	12.59***
Juvenile	22	11.0	1.0	
	Gizzard weight, g			
	N	$\bar{X}$	SD	F[a]
Peripheral	28	21.3	0.9	11.87***
Central	21	22.5	1.4	
Adult	26	22.3	1.3	9.08**
Juvenile	23	21.3	0.9	
	Caeca length, cm			
	N	$\bar{X}$	SD	F[a]
Peripheral	16	47.1	2.1	20.13***
Central	7	50.9	0.8	
Adult	7	50.9	0.8	20.13***
Juvenile	16	47.1	2.1	

[a] Significance of F: **, $P < 0.01$; ***, $P < 0.001$.

Results

Of the 49 specimens, 26 were adults and 23 were yearlings. Only adults occupied central territories (N = 21) whereas peripheral males consisted of five adults and 23 yearlings. Central males had significantly larger hearts, gizzards, and caeca than peripheral individuals (Table 1). Also, adults had larger organs compared to yearlings (Table 1). Among peripheral birds, no significant differences for heart ($P = 0.13$) and gizzard ($P = 0.63$) were found between adults (heart, N = 4, $\bar{X} = 11.9$, SD = 1.1; gizzard, N = 5, $\bar{X} = 21.5$, SD = 0.7) and yearlings (heart, N = 22, $\bar{X} = 11.0$, SD = 1.0; gizzard, N = 23, $\bar{X} = 21.3$, SD = 1.0).

There were significant relationships between heart weight and body mass ($r = 0.57$, $P = 0.0001$; Figure 1), gizzard weight and body mass ($r = 0.54$, $P = 0.0001$; Figure 2), and caeca length and body mass ($r = 0.82$, $P = 0.0001$; Figure 3). Fifty-five percent of central males and 57% of adults had heart weights greater than those predicted by the regression equation and 52% of the peripheral males and 50% of the yearlings had values higher than expected. Similar positional and age trends were noted for gizzard weights and caeca lengths.

There was no relationship in residual variation between peripheral and central males for heart weights, gizzard weights, and caeca lengths ($F = 0.01$, $P = 0.9063$; $F = 0.43$, $P = 0.5136$; $F = 1.08$, $P = 0.3095$; respectively). Non-significant results were also evident for an ANOVA of residual variation between yearlings and adults for heart weights, gizzard weights, and caeca lengths ($F = 0.06$, $P = 0.8125$; $F = 0.01$, $P = 0.9374$; $F = 1.08$, $P = 0.3095$; respectively). Thus, central males and adults did not possess disproportionately

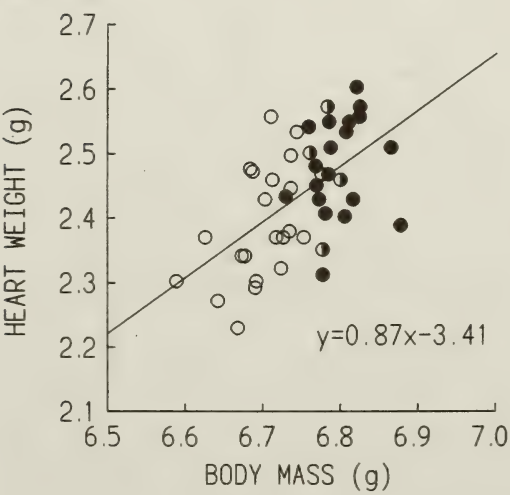

FIGURE 1. Relationship between the natural log of heart weight and body mass of 45 male Sharp-tailed Grouse. Adults in central territories are represented by solid symbols; adults in peripheral territories by half-filled symbols; and yearlings in peripheral territories by open symbols.

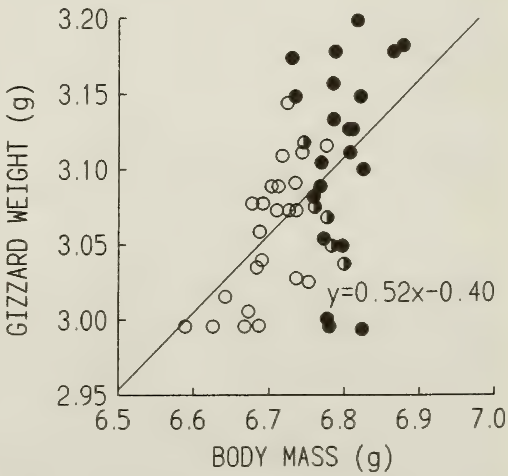

FIGURE 2. Relationship between the natural log of gizzard weight and body mass of 49 male Sharp-tailed Grouse. Adults in central territories are represented by solid symbols; adults in peripheral territories by half-filled symbols; and yearlings in peripheral territories by open symbols.

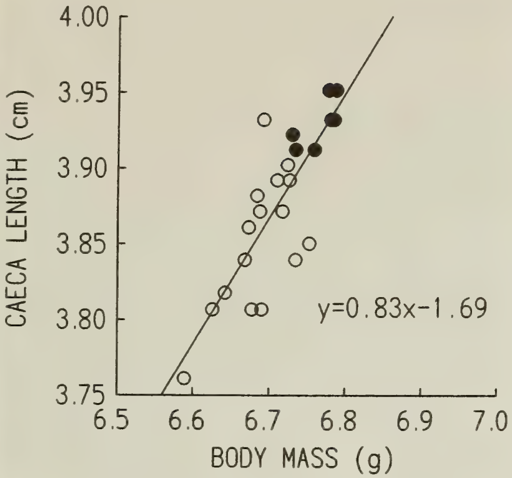

FIGURE 3. Relationship between the natural log of caeca length and body mass of 23 male Sharp-tailed Grouse. Adults in central territories are represented by solid circles and yearlings in peripheral territories by open circles.

large hearts, gizzards, and caeca compared to peripheral individuals and yearlings, respectively.

The gizzard contents of all individuals examined consisted mainly of buds and twigs of Tamarack (*Larix laricina*) and some of willow (*Salix* spp.). The seeds of the wild rose (*Rosa* spp.) were also present to a lesser extent. No differences in energy content of diet were found for; yearlings versus adults, and peripheral versus central males (Table 2).

Discussion

Older males of lekking Sharp-tailed Grouse have been shown typically to occupy central territories, with peripheral territories occupied by adults and yearlings (e.g., Rippin and Boag 1974; this study). Older males also tend to expend more energy on courtship activities than yearlings (e.g., Kermott 1982). However, relative heart size does not explain the higher level of activity maintained by central males and adults on the lek. Moreover, Tsuji et al. (1994) showed that male sharptails occupying central territories on the lek were in better body condition than their peripheral counterparts, and that adults were in better condition than yearlings. The differences in condition between these groups of birds cannot be attributed to anatomical differences in the gizzard and caeca. Although gizzard weight and caeca length in centrally located males and adults were significantly heavier and longer compared to peripherally located individuals and yearlings, respectively, these organs were not disproportionately larger. Thus, no gastro-intestinal advantage (anatomical) can be attributed to positional or age factors.

It is not surprising there were no positional or age effects with regards to diet (type and energy content), as the main plant foods in the Sharp-tailed Grouse diet are omnipresent on the muskeg (Hanson 1953). Further, sharptails rarely dig or scratch for food; therefore, it appears that snow depth, not behavioral differences, determines availability of winter and early spring food (Schmidt 1936; Marshall and Jenson 1937).

Differences in body condition in sharptails were not related to any of the variables measured. However, individual differences in condition may be related to differences in the microorganisms present. Indeed, Suomalainen and Arhimo (1945) found that microorganisms cultured from the gastro-intestinal tract (i.e., gizzard and caeca) of young galliforms had the ability to digest cellulose, but activity levels were low relative to cultures from adults. The difference in microbial activity between yearlings and adults may be related to the seasonal switch in diet common to galliforms (Pendergast and Boag 1971). During the late spring to early autumn, a highly digestible diet of berries and insects make up the sharptails' diet (Mitchell and Riegert 1994), whereas late autumn and winter bring a low quality diet of browse which is high in cellulose (Schmidt 1936; Marshall and Jenson 1937). Yearling galliforms do not appear to be able to adapt physiologically to the winter diet of browse as easily as adults (Pendergast and Boag 1971), probably due to differences in their intestinal fauna.

TABLE 2. Energy content of diet and Wilcoxon rank-sum tests between juvenile and adult males, and males occupying peripheral and central territories on leks, of Sharp-tailed Grouse.

	Quality of diet (kJ/g)		
	N	$\bar{X} \pm$ SD	Z[a]
Age			
Juveniles	22	24.2 ± 3.6	0.43^{NS}
Adults	15	24.1 ± 3.5	
Position			
Peripheral males	24	24.1 ± 3.5	0.80^{NS}
Central males	13	24.3 ± 3.7	

[a]Significance of Z: ^{NS}, $P > 0.42$.

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Effect of a Commonly-Used Nest Marker on Nest Success of Ducks in Prairie Canada

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Greenwood, Raymond J., and Alan B. Sargeant. 1995. Effect of a commonly-used nest marker on nest success of ducks in prairie Canada. Canadian Field-Naturalist 109(4): 437–440.

We evaluated the effect of a flagged-stake marker on success of duck nests in the prairie pothole region of Canada, and whether abundance of American Crows (*Corvus brachyrhynchos*) influenced results. We marked 565 nests with flagged-stake markers and 573 in relation to natural objects (e.g., rock, tree, fence-post). We detected no difference in average daily survival rates between nests with flagged vs. natural markers ($\chi^2 = 3.37$, 1 df, $P = 0.07$). Success rates averaged 10% for nests with flagged markers and 6% for nests with natural markers. The direction of the difference was consistent among areas and years ($\chi^2 = 19.9$, 17 df, $P = 0.28$). We detected no correlation among areas and years between indices of American Crow abundance and differences in daily survival rates between nests with flagged markers and nests with natural markers ($r = 0.02$, 37 df, $P = 0.91$).

Key Words: American Crow, *Corvus brachyrhynchos*, duck, nest depredation, nest marker, prairie pothole region, Manitoba, Saskatchewan, Alberta.

Studies of breeding waterfowl often involve marking nest locations so the nests can be revisited to estimate nest success (Klett et al. 1986). There has long been concern, however, that finding and marking nest locations might attract predators (Kalmbach 1937; Sowls 1955:15; Hammond and Forward 1956), thereby biasing estimates of nest success. The potential for bias appears to be greatest where egg predators include avian species that may use visual cues to find nests. Corvids, especially crows (*Corvus* spp.), are noted egg predators (e.g., Verbeek 1982; Sonerud and Fjeld 1985). The American Crow (*C. brachyrhynchos*) is an important predator of duck eggs in the prairie pothole region of Canada (Smith 1971). Picozzi (1975) found that Hooded Crows (*C. corone*) learned to use cane markers as cues to find eggs in artificial nests.

We evaluated the effect of a commonly used, flagged-stake marker (Klett et al. 1986) on success of duck nests and whether abundance of American Crows influenced results. Work was conducted in the prairie pothole region of Canada in conjunction with studies of duck recruitment (Greenwood et al. 1995) and predator abundance (Sargeant et al. 1993).

Study Area

We worked on eight study areas in 1984 and 10 in 1985; six areas were used in both years (Table 1). Each study area was 1.6 km wide x 16.0 km long and had a road or trail lengthwise through the center. Seven study areas were in parkland, a zone of deciduous woods transitional between boreal forest and prairie (Bird 1961), and five were in prairie. Habitat composition of study areas averaged 59% cropland, 16% grassland, 11% wetland, 7% odd area (e.g., < 2 ha patches of perennial vegetation along fences and around wetlands in cropland), 2% each hayland, woodland, and rights-of-way, and 1% barren (e.g., road surfaces) (Greenwood et al. 1995). Climate of the region is continental (Kendrew and Currie 1955); drought occurred during both years of study (Greenwood et al. 1995).

The predator community on each study area included at least five species of mammals and six species of birds likely to affect duck nest success by preying on eggs or females (Sargeant et al. 1993). Predator species composition varied among areas. Species believed to be of greatest consequence to nesting ducks on the greatest number of areas were Coyote (*Canis latrans*), Red Fox (*Vulpes vulpes*), Striped Skunk (*Mephitis mephitis*), Badger (*Taxidea taxus*), Franklin's Ground Squirrel (*Spermophilus franklinii*), Black-billed Magpie (*Pica pica*), and American Crow. American Crows were present on all areas.

Methods

To find duck nests (≥ 1 egg attended by a female [Klett et al. 1986]), all or portions of habitats suitable for nesting on each study area, except seeded cropland, were systematically searched three times annually (Greenwood et al. 1995). Search periods began the first week of May, fourth week of May, and second week of June. Daily searches were conducted between 06:00 and 14:00. Where possible, two-person teams searched vegetation with long (≤ 80 m) chain drags towed by vehicles (Higgins et al. 1969) or rope drags pulled by hand. Where drags could not be used effectively, field personnel used switches to flush nesting females from vegetation.

TABLE 1. Names and locations[a] of areas studied in the prairie pothole region of Canada and numbers (n) and average daily survival rates (DSR) of duck nests by type of nest marker[b] and year.

	1984				1985			
	Flagged		Natural		Flagged		Natural	
Study area and location	n	DSR	n	DSR	n	DSR	n	DSR
Parkland								
Earl Grey, Saskatchewan					24	0.9364	33	0.9432
Hanley, Saskatchewan	17	0.9152	15	0.8762	42	0.9516	42	0.9346
Inchkeith, Saskatchewan	4	0.8367	4	0.9535	39	0.9530	38	0.9276
Leask, Saskatchewan	31	0.9557	28	0.9436	59	0.9429	52	0.9279
Moore Park, Manitoba	36	0.9563	43	0.9429				
Penhold, Alberta					12	0.9667	17	0.9430
Yorkton, Saskatchewan					45	0.9473	52	0.9387
Prairie								
Ceylon, Saskatchewan	61	0.9176	59	0.9201				
Craik, Saskatchewan	3	1.0000	3	0.7857	26	0.9223	30	0.9155
Denzil, Saskatchewan	28	0.9301	24	0.9263	61	0.9016	51	0.9161
Gayford, Alberta					18	0.9652	20	0.9681
Shamrock, Saskatchewan	35	0.8790	38	0.9024	24	0.9449	24	0.9208

[a]See Greenwood et al. (1995) for latitude and longitude of study areas.
[b]Flagged marker was a 1-1.5 m stick placed 4 m from nest with a 2.5-5.0 cm flag attached at the tip. Natural marker was an existing object (e.g., rock, tree, fence-post) from which the nest location was established by measurement and compass bearing.

We used a subsample of the nests reported by Greenwood et al. (1995) to evaluate the effect of flagged markers on nest success. Each year on each study area during both the late May and mid-June search periods, field personnel attempted to mark at least 20 nests each with the flagged marker and with an existing (natural) marker. The flagged marker was a 1-1.5 m slender stick with 2.5-5.0 cm of pink plastic tape affixed to the tip, placed upright 4 m north (if possible) of the nest. Each natural marker was an existing object (e.g., rock, tree, fence-post) ≥ 4 m from the nest from which the distance and direction to the nest were measured. Each day field personnel searched for and marked nests on a study area until the desired sample of nests was obtained; the type of marker to be used at the first nest found was randomly assigned. Thereafter, for the duration of the day, nests were alternately marked with either the flagged marker or the natural marker. All nests were individually numbered and their locations were plotted on aerial photographs.

Data recorded for nests included duck species, date, location, habitat, number of eggs, incubation stage (Weller 1956; Klett et al. 1986), and type of marker. Nests were revisited about every 7-10 days until ≥ 1 egg hatched or the nest was abandoned or destroyed. Data recorded during each revisit to a nest included date, number of eggs, and fate (last visit only).

A nest was successful if ≥ 1 egg hatched (Klett et al. 1986) or ducklings were present, and unsuccessful if all eggs were destroyed or missing or it was abandoned. An abandoned nest was one with ≥ 1 whole egg unattended by a female (eggs cold). For nests that seemed to have been abandoned on the day found, we attributed abandonment to investigator influence and excluded the nests from analyses. For nests abandoned after ≥ 1 egg was depredated, we attributed abandonment to predator influence.

To estimate nest success, we first estimated daily survival rates (DSRs) by the Mayfield (1961) method, as modified by Johnson (1979). We compared DSRs of nests with flagged markers to those of nests with natural markers by the method of Johnson (1990). We related differences in estimated DSRs to abundance of American Crows. We used the density of American Crow nests from Sargeant et al. (1993) as our index of American Crow abundance. For each area-year (1 area for 1 year), we calculated the difference in estimates of DSRs of duck nests with flagged markers and those with natural markers. We then correlated the difference in DSR estimates with number of American Crow nests for each area-year. We restricted this analysis to comparisons where estimates of DSRs were based on > 30 exposure days. We weighted the DSR estimates of duck nests in each area-year by the minimum number of exposure days used to calculate the difference in DSRs in that area-year. We converted all estimates of DSRs to nest success after analyses were performed (nest success = $[DSR]^{34}$).

Results

A total of 1138 duck nests (56% in parkland, 44% in prairie) was available for evaluation; 565 were marked with flagged markers and 573 with natural markers (Table 1). Eleven species were represented, primarily Mallard (*Anas platyrhynchos*) (28%), Blue-winged Teal (*A. discors*) (24%), Northern Shoveler (*A. clypeata*) (12%), Northern Pintail (*A. acuta*) (12%), and Gadwall (*A. strepera*) (9%). The remaining (1-4% each) were American Wigeon (*A. americana*), Green-winged Teal (*A. crecca*), Canvasback (*Aythya valisineria*), Redhead (*A. americana*), Lesser Scaup (*A. affinis*), and Ruddy Duck (*Oxyura jamaicensis*). Ninety-two percent of nests were in upland or dry wetland (509 flagged marker, 533 natural marker) and 8% were in wetland (56 flagged marker, 40 natural marker).

We detected no difference in average DSRs between nests with flagged markers and those with natural markers (χ^2 = 3.37, 1 df, P = 0.07). Because of small sample size of nests in wet wetlands, we did not distinguish between those nests and nests in upland or dry wetlands. For the 18 combinations of area-year, nest success averaged 10% for nests with flagged markers versus 6% for those with natural markers; direction of the difference was consistent among area-years (χ^2 = 19.9, 17 df, P = 0.28). We detected no correlation among area-years between indices of American Crow abundance and differences in DSRs of nests marked with flagged markers and nests marked with natural markers (r = 0.02, 37 df, P = 0.91).

Discussion

We observed no effect on nest success from the flagged marker, and no relation between success of nests marked with the flagged marker and abundance of American Crows. Marked nests on most study areas were widely scattered, thus individual predators probably had little opportunity to habituate to markers. If predators were attracted to nests with flagged markers, we would expect nests with natural markers to hatch at a higher rate. On the contrary, the trend we observed tended to be the opposite of this, and was consistent among areas and between years.

Although we found duck eggs under nests of American Crows, we found no evidence that they used our marker to find nests as suggested by Picozzi (1975) for Hooded Crows. Vacca and Handel (1988), likewise, believed there was no effect from markers on predation of artificial Canada Goose (*Branta canadensis minima*) nests where Glaucous Gulls (*Larus hyperboreus*) and jaegers (*Stercorarius longicaudus* and *S. parasiticus*) were important predators. Exposed eggs and broken egg shells (Choate 1967; Dwernychuk and Boag 1972; Newton and Campbell 1975; Sugden and Beyersbergen 1986; and Vacca and Handel 1988) and movements of nesting females (Erikstad et al. 1982) may be more likely than markers to serve as cues to avian predators of the presence of eggs.

Human presence (Strang 1980) and disturbance to vegetation (Hammond and Forward 1956; Dwernychuk and Boag 1972) also have been suggested to increase vulnerability of nests to predation. We did not estimate effects of those types of disturbances, but their influence should have been consistent between nests with both types of marker in our study. Our nests were all visited by one or two persons. Placement of the flagged marker or measurement of distance to a natural marker likely caused similar disturbance to vegetation. Disturbance may be more important when nests are in lush vegetation; many of ours were in sparse grasses and woody brush (e.g., *Rosa* spp. and *Symphoricarpos* spp.) (Greenwood et al. 1995). Although Esler and Grand (1993) concluded that vegetation disturbance caused by daily visitation of nests was responsible for increased depredation of artificial nests, they detected no such effect on survival of marked duck nests visited at the 7-10 day interval that we used.

Our findings, like those of Livezey (1980), suggest that careful marking and revisiting of scattered duck nests in the prairie pothole region has little effect on estimates of nest success. We urge investigators, however, to be cautious when marking and visiting nests. As demonstrated by Picozzi (1975) and suggested by others, some predators can learn to find nests from cues left by humans. Chances for such occurring probably are greatest where investigators use conspicuous markers, exercise little caution in trampling vegetation at nests, mark large numbers of nests in local areas, or repeatedly use similar markers at the same site for several years, permitting individual predators to habituate to the marker.

Acknowledgments

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Notes

Arrow Arum, *Peltandra virginica*: A Nationally Rare Plant in the Ottawa Valley Region of Ontario

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Toner, Maureen, Nicholas Stow, and Cathy J. Keddy. 1995. Arrow Arum, *Peltandra virginica,* A nationally rare plant in the Ottawa Valley region of Ontario. Canadian Field-Naturalist 109(4): 441–442.

Arrow Arum, *Peltandra virginica* (L.) Schott & Endl., a nationally rare plant, is reported in Lanark County, Ontario. This is the first occurrence of Arrow arum reported in the Ottawa Valley region and beyond the climatically more moderate parts of southern Ontario. As such, it suggests a more extensive range in the Canadian Shield region of southern Ontario than previously suspected.

Key Words: Araceae, Arrow Arum, *Peltandra virginica*, Canadian Shield, Lanark County, nationally rare, Ontario, Ottawa Valley, range extension.

Arrow Arum, *Peltandra virginica*, a nationally rare plant (Argus and Pryer 1990), was found in Lanark County, Ontario (45°05′N, 76°14′W) by Cathy Keddy on 1 October 1994. The discovery is significant because it extends the known range of the species in eastern Ontario and Quebec northward by 90 km into the Ottawa valley region, and beyond the climatically milder parts of southern Ontario where it has been previously found.

Three clumps of Arrow Arum were found close together at the waterline of a large beaver pond, in association with Purple Loosestrife, *Lythrum salicaria*, Pickerel-weed, *Pontederia cordata*, Marsh Fern, *Thelypteris palustris*, and Sensitive Fern, *Onoclea sensibilis*. The plants appeared healthy, despite having begun to senesce. The shore, at this site, was covered by a dense stand of White Cedar, *Thuja occidentalis*. Leaves, spathe, spadix and seeds were collected from a single plant (leaving the rhizome intact), and were placed in the herbarium at the University of Ottawa (OTT). A report of the find was filed with the Natural Heritage Information Centre, Peterborough, Ontario. The NIHC has no record of any other discoveries more recent than those reported by Keddy (1984). The location of these occurrences are shown in Figure 1.

Arrow Arum is a member of the family Araceae. It is found in swamps and shallow waters, from eastern Canada and southern Maine to Florida, and west to Michigan, Missouri and Louisiana (Gleason 1952). It is rare in both Maine and Missouri (Gleason 1952), as well as in Canada (Argus and Pryer 1990), where it has been reported only in restricted sites near the Great Lakes and the St. Lawrence River. In Quebec, it has been reported in the Richelieu and Chateauguay river systems, and at sites along the St. Lawrence River between Montréal and Trois Rivières (Bouchard et al. 1983). In Ontario, it as been reported at Gananoque, the Bay of Quinte near Belleville, Wolfe Island, Long Point, in several sites in Welland County and the Niagara area, on the Severn River near Georgian Bay, on the Bruce Peninsula and on Manitoulin Island (Keddy 1984).

The pond in which the plants were found lies on the eastern edge of the Madawaska Highlands, on the Precambrian shield, at an elevation between 150 and 160 m. This is the only site of Arrow Arum to lie north of the 120 frost-free days isotherm. The Manitoulin Island sites average between 120 and 140 frost-free days per year, and all the other sites average greater than 140 frost-free days per year (Energy, Mines and Resources 1985). The production of seeds indicates that the growing season is long enough to allow completion of the plant's life cycle, but whether the seeds produced are viable is unknown. In addition, the high local abundance of Arrow Arum in St. Lawrence River and Lake Ontario sites (Dore 1966; Garwood 1965; Laking 1951) suggests that these populations are still significantly south of this species' potential northern limit.

The disjunct nature of this small population of plants strongly suggests that they were transported as seeds by waterfowl, which are protected and numerous on the property during migration. The property is private and relatively inaccessible, so that

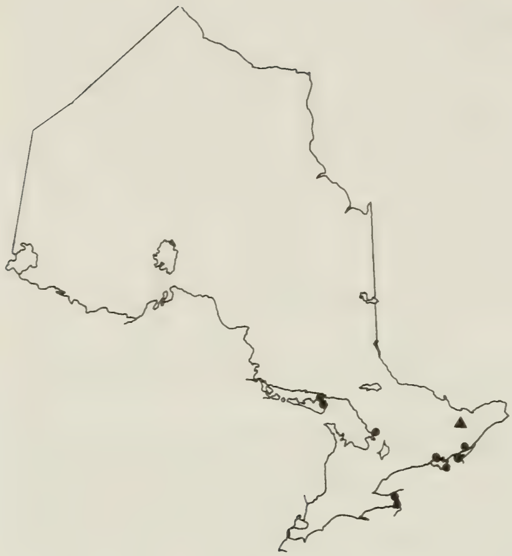

FIGURE 1. Map of Ontario showing location of recent discovery of Arrow Arum (triangle) in relation to previously reported discoveries (circles). Adapted from Keddy (1984).

human introduction is unlikely. Moreover, the seeds of Arrow Arum are reported to be eaten by waterfowl, particularly the Wood Duck, *Aix sponsa* (Fasset 1957). The introduction of Arrow Arum is believed to have occurred only recently, as the pond is regularly surveyed by the owners, who are experienced botanists. It has been suggested, however, that this species may be more common and wide-ranging in eastern Ontario than has actually been reported, due to possible confusion with Pickerel-weed (A. Crowder, personal communication). The two species are superficially similar and occupy similar habitats. Whether Arrow Arum is expanding northward or is simply overlooked, its discovery in the Ottawa Valley region suggests a potentially much more extensive range in the Canadian Shield region of southern Ontario than previously suspected.

Acknowledgments

We thank Paul Catling, at Agriculture Canada, for confirming the identity of our herbarium specimen and for his insightful discussion of the range of Arrow Arum. We thank Michael Oldham at NHIC for the information he provided and those people who gave us access to their herbaria: Paul Catling, Adele Crowder (Queens University), and Mike Shchepanek and Cheryl McJannet (Canadian Museum of Nature). We thank Paul Keddy for his advice and Michael Muller for his help in producing the map of Ontario.

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Coprophagy by Wilson's Storm-petrels, *Oceanites oceanicus,* on North Atlantic Right Whale, *Eubalaena glacialis,* faeces

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Kraus, Scott D., and Gregory S. Stone. 1995. Coprophagy by Wilson's Storm-petrels, *Oceanites oceanicus*, on North Atlantic Right Whale, *Eubalaena glacialis*, faeces. The Canadian Field-Naturalist 109(4): 443–444.

Wilson's Storm-Petrels, *Oceanites oceanicus*, have been observed to hover and apparently feed in the vicinity of several species of whales. Here we confirm that they occasionally feed upon the faeces of North Atlantic Right Whales, *Eubalaena glacialis.*

Key Words: Wilson's Storm-petrels, *Oceanites oceanicus*, North Atlantic Right Whale, *Eubalaena glacialis*, Canada, coprophagy, faeces.

In a review of associations between seabirds and cetaceans, Evans (1982) suggested that sightings of Pilot whales (*Globicephala* spp.) and Risso's Dolphins (*Grampus griseus*) with storm-petrels indicated feeding by petrels upon whale faeces. Here we report observations that confirm this activity by Wilson's Storm-petrel (*Oceanites oceanicus*) on the faeces of the North Atlantic Right Whale (*Eubalaena glacialis*).

As part of extensive shipboard surveys for Right Whales conducted in Canadian waters since 1980, observations on whales, associated seabirds, oceanographic conditions, and other biological phenomena were collected. On 6 September 1983, about 55 km south of the southern tip of Nova Scotia, a right whale was seen to defecate within 20 m of our survey vessel. Immediately afterwards, a Wilson's Storm Petrel approached the area and began feeding on the floating faeces.

Right Whale defecation is frequently observed during courtship activities or when the whales are startled. Faeces are orange or reddish-brown in color, and are usually accompanied by an oil slick and a foul odor. On 35 occasions between 1981 and 1986, Right Whale faeces were collected and analyzed for prey species. All samples analyzed contained primarily the remains of the calanoid copepod *Calanus finmarchicus* (identified by S. K. Katona, College of the Atlantic, Bar Harbor, Maine, 04609).

To determine the potential food value to a petrel, four faecal samples were subjected to calorimetric analysis (Table 1). The low fat content in these samples indicates that whale faeces are probably not an important source of food for petrels. However, because large oil slicks are observed around most whale defecations and the samples were only the accreted lumps of faecal material, the material analyzed probably under-represented the fat available to a petrel feeding in a defecation slick.

Observations made since 6 September 1983 indicate that petrels frequently divert flight paths to hover over a whale's diving slicks. We suspect that petrels use the significant olfactory cues available to locate Right Whale feces, as suggested by Payne et al. (1983) for dead whales, although they may also use the visual cue of the oil slick. Petrels may also be looking for food flushed through the baleen, but Right Whales do not feed near the surface in Canadian waters (Murison and Gaskin 1989) and this possibility seems unlikely. It is also possible that other prey organisms of interest to Petrels are attracted to the faeces, although we found no living zoo-

Table 1. Calorimetric analysis of Right Whale faeces.

	Moisture	Protein	Fat	Ash	Carbohydrate	KCal/100 g
Adult 20 August 1981	92.4%	3.6%	0.9%	2.8%	0.3%	24
Adult 16 September 1981	84.5%	8.0%	0.9%	4.2%	2.4%	50
Adult 25 September 1982	88.5%	6.8%	1.1%	2.5%	1.1%	42
Calf 12 August 1982	80.4%	4.0%	10.8%	3.0%	1.8%	116

plankton in all 35 faecal samples examined. Instead, these data confirm coprophagy as an additional reason for associations between petrels and large baleen whales.

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Extensions to the Known Range for Three Maine Reptiles

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Applegate, Roger D., Randall C. Spencer, and Frederick M. Trasko. 1995. Extensions to the known range for three Maine reptiles. Canadian Field-Naturalist 109(4): 444-446.

In Maine, the known range of the Snapping Turtle, *Chelydra serpentina*, is here extended about 18 km north to Moosehead Lake, where four individuals observed laying eggs indicate breeding there. The Northern Water Snake, *Nerodia sipedon sipedon*, was found 106 km north at Lunksoos Stream, Penobscot County. The Brown Snake, *Storeria dekayi*, was discovered at Swan Island, 40 km northeast of a previous record in the southern portion of the state, and at Orneville Plantation, 48 km east of a previous northeastern disjunct.

Key Words: Snapping Turtle, *Chelydra serpentina*, Northern Water Snake, *Nerodia sipedon sipedon*, Brown Snake, *Storeria dekayi*, new records, Maine.

From 1984 to 1988, the University of Maine, Maine Audubon Society, Maine Chapter of the Nature Conservancy, Maine Natural Heritage Program, and the Maine Department of Inland Fisheries and Wildlife conducted the Maine Amphibian and Reptiles Atlas Project (MARAP) (Hunter et al. 1992). During the hiatus between 1988 and the publication we have added extensions for three reptile species within the state.

SNAPPING TURTLE, *Chelydra serpentina*: Four individuals were seen (by RDA) laying eggs at Moosehead Lake (44°41′30″N, 69°43′10″W), Keno Township (Figure 1) on 21 June 1989. Egg-laying occurred in sandy soil, 3 m above a gravel beach among 1 m high Red Spruce (*Picea rubens*). Although specimens were not handled each of the females was estimated to be approximately 500 mm carapace length. Although this record only extends the known range for the species about 18 km north, it is notable as it is on the Moosehead Plateau, a northwestern highland orientated southwest to northeast, beginning in Franklin County where Coulter (1992) regarded them absent. Bleakney (1958) plotted a record in this area, but details were not given and are not available now (Bleakney, personal communication to F. R. Cook, 1995). The sightings also establish nesting in the area, although the success of nests at this locality remains to be determined. In the adjacent Maritime provinces of Canada, Snapping Turtles are not considered abundant outside of Herpetofaunal Section 2A (Bleakney 1958: map 5) which is delimitated as including the lower St. John River Valley, New Brunswick, and part of southwestern Nova Scotia. Southern and central Maine are climatically similar to Bleakney's Section 2A (which he based on a value obtained by multiplication of the mean July temperature and the length of the growing season) and if its border were extended into Maine it would correspond to the edge of the Moosehead Plateau. McAlpine and Godin (1986) augmented the range of Snapping Turtles in New Brunswick with new records in river valleys and in coastal areas beyond Herpetofaunal section 2A, but not into the highland region of the northern portion of that province. Abundance at these additional localities is not documented.

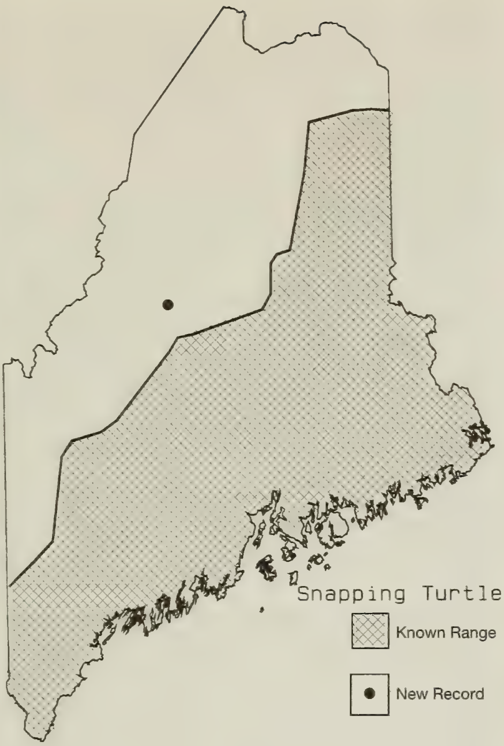

FIGURE 1. Distribution of the Snapping Turtle, *Chelydra serpentina serpentina*, in Maine. The hatched area depict the limit based on Coulter (1992) and the solid circle is the observation from Moosehead Lake (see text).

FIGURE 2. Distribution of the Northern Water Snake, *Nerodia sipedon sipedon*, in Maine. The hatched areas depict the range based on Riter (1992) and the solid circles are the Luckoos Stream observation and the New Brunswick Museum specimen from Nashs Lake, Calais (see text).

NORTHERN WATER SNAKE, *Nerodia sipedon*: A 600 mm specimen was handled by RCS and FMT at Lunksoos Stream, T4R7 WELS, Penobscot County (45°58′11″N, 68°40′00″W), on 13 August 1990 (Figure 2). The snake was captured and released during electrofishing surveys. In this location Lūnkoos Stream has a 1-3% gradient over a boulder/gravel substrate. The stream is characterized by alternating riffles and runs and is lined with mixed growth Yellow Birch (*Betula alleghaniensis*), American Beech (*Fagus grandifolia*), and Sugar Maple (*Acer saccharum*). Approximately 500 m downstream there is Beaver (*Castor canadensis*) pond flowage. This record is approximately 106 km north of the nearest previous confirmed observation at Stetson, Penobscot County (44°53′N, 69°05′W) (Ritter 1992), and thus well north of the area between the Penobscot River and eastern Washington County where Ritter knew of only two unconfirmed reports. A specimen in the new Brunswick Museum (NBM 952; D. F. McAlpine, personal communication) from Nash's Lake, Calais (45°06′05″N, 67°12′05″W) in 1969, provides confirmation of this species' occurrence near the New Brunswick border.

BROWN SNAKE, *Storeria dekayi*: One 114 mm total length specimen was handled by RDA on Swan Island, Perkins Township (44°04′00″N, 69°47′55″W) 18 July 1988 and one 111 mm total length in Orneville Plantation (45°11′05″N, 68°53′50″W) 7 August 1991 (Figure 3). The Perkins Township record is 40 km northeast of the previous known eastern record in southern Maine from an island in the Kennebec River (Mazurkiewicz 1992). The snake was found beneath a pile of clapboards from an abandoned house. The surrounding habitat was tall grass above a steep embankment sloping to the river. The Orneville record is 48 km east of an apparently disjunct locality, Solon (44°57′N, 69°52′W). The snake was found beneath a pile of firewood in an ungrazed pasture. A rock wall and some 10-15 m tall White Birches (*Betula papyrifera*) were adjacent to the site.

FIGURE 3. Distribution of the Brown Snake, *Storeria dekayi*, in Maine. The hatched ares depict the limit based on Mazurkiewicz (1992) and the solid circles are the observations at Swan Island and Orneville Plantation (see text).

Acknowledgments

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Evidence of Overwinter Growth in Peary Caribou, *Rangifer tarandus pearyi*, Calves

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Larter, Nicholas C., and John A. Nagy. 1995. Evidence of overwinter growth in Peary Caribou, *Rangifer tarandus pearyi*, calves. Canadian Field-Naturalist 109(4): 446–448.

Female Peary Caribou calves were collected on Banks Island during early winter (November-December 1993) and mid-winter (February 1994). Calves collected in February (aged 8 months) had significantly larger femur, tibia, and metatarsus bones than those collected in November/December (aged 5–6 months), possibly indicating overwinter growth.

Key Words: Peary Caribou, *Rangifer tarandus pearyi*, growth, legbones, calves, Banks Island, Northwest Territories.

Freezing rains which occurred during October 1993 on Banks Island resulted in about 50% of the traditional Caribou wintering range exhibiting severe icing conditions (Larter and Nagy 1994). These conditions, coupled with the fact that two orphaned calf Peary Caribou shot in early November were considered to be in poor condition by residents of Sachs Harbour, raised concerns of a potential winter die-off of Caribou because of restricted access to winter forage. Winter die-offs related to autumn freezing

rains had occurred in previous winters: 1987-1988, 1988-1989, and 1990-1991 (Nagy et al. *in press*). One of the management recommendations of the Wildlife Management Advisory Committee (WMAC) meeting held in response to the concerns raised by residents of Sachs Harbour was that a limited collection of Peary Caribou be conducted in order to document physical condition, and determine whether or not they were already showing signs of severe undernutrition.

Total body weight loss during winter has been well documented in Caribou and Reindeer (Dauphiné 1976; Reimers 1980; Boertje 1985; Adamczewski et al. 1987; Tyler 1987; Leader-Williams 1988). Intrinsic cycles of growth and fattening have been alluded to as adaptations for survival in seasonal environments with long, predictable periods of potential undernutrition (Tyler and Blix 1990), but losses in total body weight do not preclude growth. In order to attain full adult size within two years, winter growth may be necessary for high arctic Caribou and Reindeer.

Banks Island Peary Caribou are listed as an endangered species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The July 1994 population estimate was 709 >1 year-old animals (Nagy and Larter, unpublished data). The collection of calves was limited to ten of which no more than six could be females. Calves cannot be accurately sexed at a distance during their first winter. Seven female calves, including one of the two calves shot in early November, and six, one in December and five in February, were a subsample of the animals collected during two time periods: 27 November to 12 December 1993 and 9 to 18 February 1994. Four adults were also collected. The seven female calves likely represent 10% of the population of female calves on Banks Island and therefore a larger sample, preferable under other circumstances, could not be justified for this population. This note compares bone lengths of female calves collected during the two periods.

Animals were stalked and shot in the neck for a quick kill and the intact deboned right hind leg was collected. In the laboratory, the frozen leg bones were thawed, separated and cleaned. Calipers were used to measure the lengths of the femur, tibia, and metatarsus following Langvatn (1977). To determine whether leg bone lengths were larger in calves between calves collected in February than those collected in November/December, we used a Mann-Whitney U-test. If bone lengths were significantly larger in February than in November/December, this might indicate growth during the animals' first winter. Calving on Banks Island occurs during late May and June, with the majority of calves being born during the first two weeks of June (Urquhart 1973). Following Dauphiné (1976), we used June as the 0 age month.

Calves collected during February (n=5) had significantly ($\underline{P}<0.05$) longer femur, tibia, and metatarsus bones than calves collected during November/December (n=2): medians 20.85 versus 22.35 cm, 23.80 versus 25.66 cm, and 21.74 versus 23.41 cm respectively. (Table 1). Based upon Dauphiné's (1976) definition of a period of growth, these data indicate at least a two-month period of growth (December-February) for female Peary Caribou calves during winter of 1993-1994. Whether growth continues beyond February is unknown.

Both Barren Ground Caribou (*Rangifer tarandus groenlandicus*)(Qamanurjuaq) and Svalbard Reindeer (*Rangifer tarandus platyrhynchus*) females grow rapidly and usually attain adult size within 24–27 months (Dauphiné 1976; Tyler 1987). Growth of Qamanurjuaq Caribou occurred during summer, ceasing in winter (Dauphiné 1976). Dauphiné (1976) reported the average monthly rate of growth of the metatarsus of female Caribou aged 0–6 months was 1.4 cm (n=38) compared to 0.1 cm (n=29) for animals aged 7–12 months. However, Tyler's (1987) reported growth curves of the femur and hindfoot of Svalbard Reindeer question whether their growth ceased during winter. Unfortunately, direct evidence of growth during winter was lacking because his 0 age class contained animals aged 3-11 months.

Recently, Ouellet (1992) documented overwinter skeletal growth of calves in a rapidly increasing pop-

TABLE 1. Bone lengths of female calf Peary Caribou collected on Banks Island during winter 1993-1994.

Collection Date	Age (months)	Femur (cm)*	Tibia (cm)*	Metatarsus (cm)*
1993 November	5	20.84	23.41	21.48
1993 December	6	20.85	24.18	21.99
1994 February	8	21.93	25.63	23.51
1994 February	8	21.99	25.70	23.41
1994 February	8	22.35	25.66	22.99
1994 February	8	22.53	25.48	23.24
1994 February	8	23.04	26.33	24.08

*Measurements were initially taken to 0.001 inch and converted to centimetres for comparison with published data on other populations.

ulation of Barren Ground Caribou reintroduced to Southampton Island, Northwest Territories. This was the first documented case of overwinter growth in Barren Ground Caribou. Mean metatarsus lengths increased from 22.16 cm (n=7) to 23.29 cm (n=7) for female calves aged 5 and 11 months respectively. These values are remarkably similar to our findings for female calves aged 5–6 and 8 months respectively. Overwinter growth of calves on Southampton Island has been attributed to lack of Wolf (*Canis lupus*) predation (predators are absent on the island), and current high per capita abundance of both summer and winter forage, a situation dissimilar to that of mainland Barren Ground Caribou populations. Arctic Wolves are present on Banks Island and prey on Caribou.

Our data suggest that Peary Caribou calves continued to grow between December and February in 1993-1994. These data could be biased in that our November/December sample may have come from calves born early (mid-May), while the February sample may have come from calves born late (mid-June). However, growth still occurred.

Possibly, these data are indicative of physiological and growth differences between high arctic and Barren Ground Caribou. Femur lengths of both 6 and 8-month-old Peary Caribou females ranged from 20.84–22.53 cm, and were similar to those of 0 and 1-year-old Svalbard Reindeer [range 15.5–22.0 cm] (Tyler 1987). Metatarsus lengths of newborn (aged 0 months) female Qamanurjuaq Caribou ranged from 22.0–25.0 cm, and were similar to those of 8-month-old Peary Caribou females (range 23.0-24.1 cm); by five months of age, female Qamanurjuaq Caribou metatarsi were 5-12 cm longer (Dauphiné 1976) than 8-month old Peary Caribou. However, metatarsus lengths of 5 and 11-month-old Barren Ground Caribou females from Southampton Island were similar to those of Banks Island Peary Caribou. Unfortunately, metatarsus lengths of newborn (aged 0 months) females from these two populations are lacking.

Our data are consistent with winter growth, and with Tyler's (1987) implication of overwinter growth in Svalbard Reindeer. Overwinter growth in the Southampton Island population of Barren Ground Caribou may be related to the reintroduction of animals into a predator free and forage abundant environment. Erupting populations are typified by females attaining sexual maturity at younger ages than those found in stable populations (Caughley 1970), thus implying rapid growth rates in order to attain a threshold size necessary to reproduce.

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Wetland Habitat Use by the Black Rat Snake, *Elaphe obsoleta*, in Eastern Ontario

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McAllister, Andrew J. 1995. Wetland habitat use by the Black Rat Snake, *Elaphe obsoleta,* in eastern Ontario. Canadian Field-Naturalist 109(4): 449-451.

Wetland habitat use by the Black Rat Snake, *Elaphe obsoleta*, in the form of a swamp, is documented at Charleston Lake Provincial Park, Ontario. Three of seven individuals radio-tracked during the summers of 1990 and 1991 were found to exhibit a seasonal pattern of wetland habitat use, with the snakes initially spending the majority of their time in a swamp during the month of June. As the summer progressed, the percentage of total observations of the snakes in the swamp decreased. This observed pattern of use of a wetland habitat may have coincided with breeding activity of birds or perhaps the snakes were responding to the forest/swamp ecotone. In light of this species, limited range in Canada and the idea fostered in the literature that associates this snake with non-aquatic habitats, potential use of wetlands by Black Rat Snakes should be examined to aid in the better understanding of this species, and hence lead to better management in the northern periphery of its range.

Key Words: Black Rat Snake, *Elaphe obsoleta*, radiotelemetry, wetland habitat, Charleston Lake, Ontario.

Presently in Canada, the Black Rat Snake's (*Elaphe obsoleta*) distribution is limited to a population in eastern Ontario and a few isolated populations along Lake Erie, all disjunct from the main part of the species' range (Weller and Oldham 1988). This has led to the recommendation that the Black Rat Snake be classified as a vulnerable species in Canada (H. J. Parsons. 1990. The status of the Black Rat Snake, *Elaphe obsoleta,* in Canada unpublished document, National Parks, Canada). Therefore, we need studies that reveal aspects of its ecology and natural history relevant to conservation and management.

Generally, the Black Rat Snake's preferred habitat consists of woodlands and uplands away from water, resulting in this species being known as the highland black snake or mountain black snake in some parts of its range (Cook 1984; Conant and Collins 1991). Previous studies on this species make no reference to it regularly utilizing aquatic or wetland habitats (Fitch 1963; Stickel et al. 1980; Weatherhead and Charland 1985, Weatherhead and Hoysak 1989, Durner and Gates 1993), though Durner and Gates (1993) and Weatherhead and Hoysak (1989) found this species crossing aquatic habitats. By contrast, my study of habitat use by Black Rat Snakes shows that wetland habitats may be used more frequently in some populations.

Habitat selection by organisms is partially dictated by resource availability (Krebs 1985). In the case of the Black Rat Snake, this may be in the form of prey types (Weatherhead and Charland 1985; Durner and Gates 1993), nesting sites (Durner and Gates 1993), and shedding sites (Weatherhead and Charland 1985).

The objectives of this study are to document the use of a wetland habitat, a swamp, by the Black Rat Snake and to examine the seasonal pattern of this use.

Study Area

The study was conducted at Charleston Lake Provincial Park (44° 30′N, 76° 02′W), located in southeastern Ontario approximately 20 km north of Lansdowne, Ontario. The topography of the area is typically that of the Frontenac Axis, part of the Canadian Shield that extends through the area (Wilson 1970). The vegetation of the area is dominated by the mixed forest of the Great Lakes-St. Lawrence lowlands (Hosie 1990) with a few patches of open areas (abandoned fields and rocky areas).

The wetland habitat in question, a swamp crossed by the main boardwalk in the park, is found at the end of a shallow bay in Charleston Lake and contains water year-round. The portion of the wetland nearest to the lake is a marsh dominated by cattails (*Typha* spp.). Farther back, the swamp consists of patches of vegetation dominated by dead and dying Silver Maple (*Acer saccharinum*), willow thickets (*Salix* spp.) and dense ground vegetation, with numerous hummocks scattered throughout.

Methods

Habitat use by seven Black Rat Snakes was monitored using radiotelemetry at the park during the summer of 1990 and 1991 as part of a study conducted by the Ontario Ministry of Natural Resources. All snakes were over 1.5 m in total length and caught opportunistically. Radio transmitters were implanted subcutaneously in the snakes (Weatherhead and Anderka 1984), and after a recov-

ery period of approximately two weeks, were released at their point of capture.

The monitoring periods for the three radio-tracked snakes found in the swamp were as follows: a female Black Rat Snake was monitored from 14 August 1990 until the beginning of July 1991 when it was believed that the snake had shed its transmitter during the period around ecdysis. Two male Black Rat Snakes were monitored from 17 June 1991 until May 1992. Monitoring of all seven snakes was generally done once per day on non-rainy days during the months of June, July and August, and at irregular intervals during May when the snakes emerged from their hibernacula and during September and October until they entered their hibernacula permanently for the winter. The number of snake-tracking days per month ranged from 12 to 25 per snake for June through August.

Results and Discussion

Three snakes used the swamp habitat during the early summer months (Figure 1). There was no direct evidence of wetland or aquatic habitat use by the remaining four radio-tracked snakes. An analysis of their home ranges using the convex polygon method (Jenrich and Turner 1969) revealed an aquatic habitat component to three of the four snakes' home ranges in the form of a lake and an abandoned beaver pond (McAllister unpublished report). This may indicate that water did not hinder their movements. In other habitat studies, Black Rat Snakes are known to cross bodies of water (Weatherhead and Hoysak 1989; Durner and Gates 1993), but they rarely have been reported to make regular use of such habitats (cf. Fendley 1980).

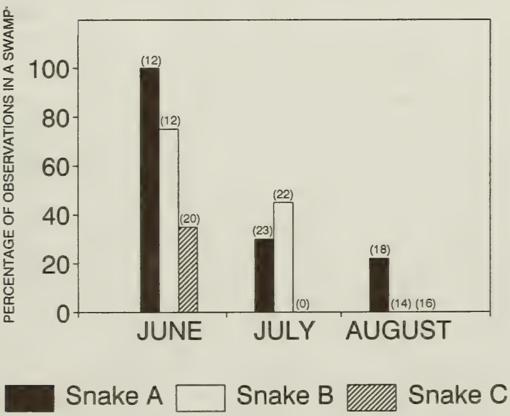

FIGURE 1. Monthly breakdown of observations of three Black Rat Snakes in a swamp habitat in Eastern Ontario. Snake B and snake C have zero observations in the swamp habitat for August. Snake C has no data for the month of July. The observations for snakes A and B are based on the summer of 1991. The observations for snake C are based on the summers of 1990 (August) and 1991 (June). The numbers in brackets indicate the number of days in the month that each snake was tracked.

Black Rat Snakes were found in the swamp mainly in June and less so in July and August (Figure 1). No snakes were seen to use the swamp in May, September, or October, although this was based only on a few observations (1–5) for any of these months. None of these observations were made in the swamp habitat. This may correspond to the suggestion by Weatherhead (1989) that there is an affinity towards the hibernaculum site during the months prior to and just after hibernation. This general trend of decreasing occurrence in the swamp habitat as the summer progresses may reflect changes in the breeding cycle of birds. Most birds in Ontario have laid eggs and are raising young during the months of June and July (Peck and James 1983), and it is well documented that Black Rat Snakes prey upon birds and their eggs and young (Fitch 1963; Jackson 1970; Fendley 1980; Aldrich and Endicott 1984; Weatherhead and Charland 1985; Hensley and Smith 1986) with Stickel et al. (1980) finding the highest incidence of birds in the snake's diet during May to July. This would imply that swamps have higher breeding bird densities than surrounding habitats. No specific references were found comparing densities of breeding birds in swamps and surrounding habitats though breeding birds were found to more abundant in a marsh (Edwards *et al.* 1981) and a riparian forest (Blem and Blem 1975) than in adjacent forested habitats.

It is also possible that the Black Rat Snakes were selecting the forest/swamp ecotone as the abundance and diversity of breeding birds are generally higher in ecotones (Smith 1974). This possibility could not be addressed in this study as the exact location of the snakes in the swamp was not always recorded due to limited accessibility to the swamp. Weatherhead and Charland (1985) found a strong association with an ecotone during the bird breeding season except that the ecotone was a forest/field edge. Durner and Gates (1993) also found that Black Rat Snakes demonstrated a preference for the forest edge but detected no seasonal differences to this preference. This may indicate reasons other than nesting birds as factors influencing the snakes, selection of the forest/field ecotone (Durner and Gates 1993). During the course of this radio telemetry study at the park, association with a forest/field ecotone was an infrequent occurrence (personal observation) but this may be a simple reflection of the low availability of this type of ecotone.

The characteristics of the swamp in this study area may have influenced the selection of this habitat by the Black Rat Snakes as none of the observations of snakes in this wetland habitat occurred in the cattail marsh (personal observation). With the presence of many dead and dying standing trees in the swamp,

the Black Rat Snakes would have had access to the breeding bird species in these areas as these snakes are well known for their climbing abilities (Jackson 1976). Other resources available to the snakes in this habitat were shedding sites. One of the radio-tracked snakes shed its skin in a large hollowed out stump and the presence of other Black Rat Snakes and shed skins around the stump indicated that this may have been a communal site for ecdysis (personal observation). Many Black Rat Snakes using the same area for ecdysis has been previously documented in the literature (Stickel et al. 1980).

In view of these preliminary findings, further research may be warranted and should include: long term monitoring studies in areas where Black Rat Snakes are known to frequent wetlands in order to determine the importance of these habitats in the overall habitat mosaic used by this snake; and the examination of different wetland types to see if there are characteristics of wetlands that Black Rat Snakes respond to.

Though this may be an isolated incident of wetland habitat use by the Black Rat Snake, the idea fostered in the literature of the Black Rat Snake not being associated with these habitats may have resulted in potential wetland habitats not being examined for this species. With habitat destruction being the principal cause of decline in threatened and endangered North American snake populations (Dodd 1987), and in light of this species, limited range in Canada, the loss of such potential habitats could have serious effects on the continued survival of the species.

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Influence of Harassment by Wolves, *Canis lupus*, on Barren-ground Caribou, *Rangifer tarandus groenlandicus*, Movements Near the Burnside River, Northwest Territories

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Scotter, George W. 1995. Influence of harassment by Wolves, *Canis lupus*, on Barren-ground Caribou, *Rangifer tarandus groenlandicus*, movements near the Burnside River, Northwest Territories. Canadian Field-Naturalist 109(4): 452–453.

A failed Wolf (*Canis lupus*) attack on Barren-ground Caribou (*Rangifer tarandus groenlandicus*) changed the movement pattern of a postcalving herd near the Burnside River on 1 July 1992. Three attacking Wolves caused the caribou to reverse their direction of travel, recross a river, and return the direction from which they had come.

Key Words: Wolf, *Canis lupus*, harrassment, Barren-ground Caribou, *Rangifer tarandus groenlandicus*, movements, Northwest Territories.

From 27 June to 10 July 1992, I participated in a raft trip down the Burnside River, Northwest Territories. On 1 July our party observed thousands of Caribou (*Rangifer tarandus groenlandicus*) moving slowly in a northeasterly direction. A number of groups of Caribou swam across to the north side of the river during the day, giving our party the opportunity to observe hundreds of animals at close range. The migratory movement was composed of maternal cows and their newborn calves with some calfless cows, juveniles, yearlings, and a few large bulls. The afternoon was sunny and hot with a temperature of about 22°C. I estimated the size of the herd across the river (66°23′N and 109°25′W) at 20 000 animals including several hundred Caribou resting on large snowbanks. The herd consisted of several loosely spaced groups that were spread over an area about 5 km long and up to 2 km wide. These Caribou are believed to be part of the Bathurst herd, which has expanded in numbers over several years. This herd calves during June, with the peak of calving usually coming in mid June (cf. Kelsall 1968: 177-181).

About 18:30 we observed three Wolves (*Canis lupus*) across the river near its bank (Figure 1A). After several minutes the Wolves moved upslope, in single file, for about 1 km towards the Caribou. At a distance of approximately 300 m and at an elevation of about 300 m, all three Wolves simultaneously ran at the herd (Figure 1). Two Wolves moved up to the right, somewhat behind the head of the herd, while the third moved up and to the left. The charging Wolves caused the advanced part of the herd to reverse direction and move southwest. For a few minutes the Caribou at lower elevations continued to move east, forming a horseshoe shape around the three Wolves with the open end towards the east (Figure 1C). Shortly after, the horseshoe formation broke down and many of the Caribou formed a closely massed aggregation (Figure 1D). The tight formation may be an anti-predator strategy. It may have also helped the cows find their calves. Within a few minutes, the Caribou swam the river and moved to the southwest, almost the opposite direction of movement we observed during the day.

The Wolves' attack was unsuccessful and appeared to be more of a testing of the herd rather than an earnest endeavor. None of the Wolves got closer than within 20 m of a Caribou. After the attack the Wolves continued up the slope (Figure 1D), with one Wolf rolling in the snow after the chase.

In most Wolf attacks described by others, once an individual Caribou was targeted, there usually was relatively little further disturbance to the herd except for the individual(s) being singled out and their closest neighbors (F. L. Miller, personal communication, 1993). However, one instance of similar Caribou behavior to that reported here was photographed during spring migration of a large Barren-ground Caribou herd in April 1949 (Banfield 1951: Figure 21). The Wolf-Caribou encounter reported here elicited an unusually strong final response by the Caribou herd. In this case, the Wolf attack completely changed the direction of movement of the aggregation. This may relate to Caribou being more nervous near water crossings because predators tend to congregate at such sites (Miller 1982). It was not possible to make further observations on this herd to see if they eventually resumed their original route or continued southwest. The full impact of the change in their movement pattern is therefore unknown, but the additional expenditure of energy to recross a still ice-filled river alone could be an important drain on the calves at a critical time of the year even if their change of direction was not permanent.

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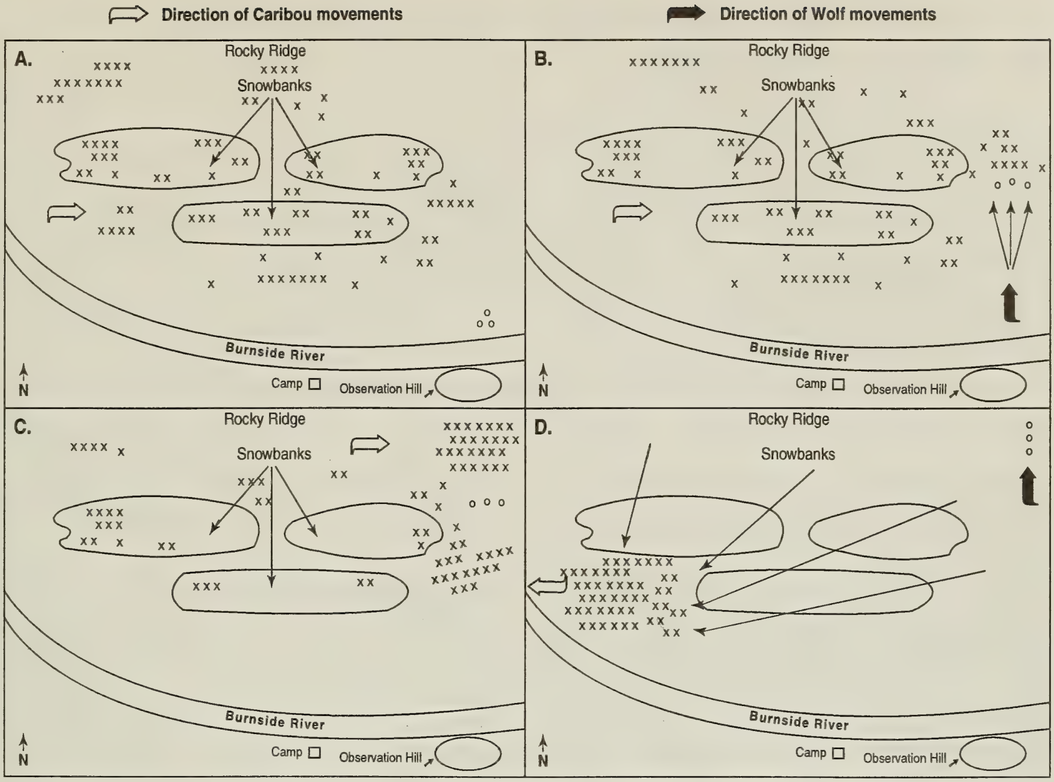

FIGURE 1. Schema of a migratory Caribou herd response to an encounter with three Wolves, Burnside River, Northwest Territories, 1 July 1992: (A) pre-attack setting, migrating Caribou and location of Wolves; (B) initial Caribou responses upon approach of Wolves; (C) apparent anti-predator strategy maneuver by Caribou herd to the Wolf attack; and (D) final strong response by Caribou herd to the Wolf harassment and reversal of direction of migration. Each x represents 25 or more Caribou; each ○ represents a single Wolf.

this note. The rafting trip occurred while I was naturalist for Whitewolf Expeditions Limited. Three companions, Barry Beales, Douglas Dolman, and Lynn Hancock, also witnessed the events described above.

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First Record of the Algal Genus *Basicladia* (Chlorophyta, Cladophorales) in Canada

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Colt, L. C., Jr., Raymond A. Saumure, Jr., and Suzanne Baskinger. 1995. First record of the algal genus *Basicladia* (Chlorophyta, Cladophorales) in Canada. Canadian Field-Naturalist 109(4): 454–455.

Five species of turtles (*Chelydra serpentina*, *Clemmys guttata*, *Chrysemys picta marginata*, *Emydoidea blandingii* and *Graptemys geographica*) from Canada were found to harbor algae of the genus *Basicladia*. This is the first report of *Basicladia* in Canada as well as the first from *Clemmys guttata* throughout its eastern North American range.

Key Words: Algae, *Basicladia*, Snapping Turtle, *Chelydra serpentina*, Spotted Turtle, *Clemmys guttata*, Painted Turtle, *Chrysemys picta*, Blanding's Turtle, *Emydoidea blandingii*, Map Turtle, *Graptemys geographica*, Ontario, Quebec, Canada.

Collins (1907) described the chlorophycean alga *Chaetomorpha chelonum* taken from the back of a Painted Turtle (*Chrysemys marginata*) from Oakland County, Michigan. Hoffman and Tilden (1930) revised his descriptions based on collections from Minnesota, and assigned *C. chelonum* to a new genus *Basicladia*, and described two species, *B. chelonum* and *B. crassa*. Subsequent workers have collected *Basicladia* from snails (Normandin and Taft 1959), freshwater clams (Curry et al. 1981), and ceramic tile (Blum 1984) in addition to a number of species of turtles.

Subsequent collections of *Basicladia* have been made in 19 other states. Of significance to the present report is that in addition to the records cited above, it has been found in the northern border states of Wisconsin (Edgren et al. 1953), Illinois (Edgren et al. 1953; Reilly 1976), Indiana (Edgren et al. 1953), Ohio (Tiffany 1937; Walker et al. 1953; Normandin and Taft 1959), New York (Colt, unpublished data) and Maine (Chute 1949; Colt, unpublished data). Additional records have been published for Michigan by Lagler (1943), Gibbons (1968), and by Belusz and Reed (1969), as well as Minnesota (Ernst and Ernst 1973).

Although its taxonomic position as a distinct genus has been questioned (Hoek 1976), most writers have adopted the genus *Basicladia* as assigned by Hoffman and Tilden. Commonly suggested to occur only on turtles (Smith 1950; Ducker 1958; Edgren et al 1953; Neil and Allen 1954, and others), *Basicladia* has, however, been reported from other substrates such as freshwater clams (Curry et al. 1981), porcelain (Yoneda 1952), mortar and peach seeds (Proctor 1958), ceramic disks (Blum 1984) and freshwater snails (Normandin and Taft 1959). In LCC's laboratory *Basicladia* has been grown on clay flower pots and polystyrene plastic. The most comprehensive works on *Basicladia* are those of Proctor (1958), and Ernst and Norris (1978).

Study Area and Methods

A study was conducted by R. A. Saumure, Jr., on four species of turtles inhabiting the Big Creek National Wildlife Area, Long Point, Haldimand-Norfolk Regional Municipality, Ontario, Canada. Sampling took place 1 May to 30 August 1993 for the Snapping Turtle, *Chelydra serpentina*, Painted Turtle, *Chrysemys picta marginata*, Spotted Turtle, *Clemmys guttata*, and Blanding's Turtle, *Emydoidea blandingii*, and from 15-21 April 1994 for additional records of *Clemmys guttata*. *Basicladia* was also collected from an incidental capture of a Map Turtle, *Graptemys geographica*. Furthermore, *Basicladia* was found in samples taken from two *Chelydra serpentina* captured in Pontiac County, Québec on 22 and 24 May 1993.

Turtles were captured by hand, dip net or baited hoop traps, and samples of algae were removed by shaving a thin layer of scute from each turtle with a scalpel. The algae were preserved in Transeau's Fluid (Prescott 1962) or 5% Formalin. Algal identification was completed in the laboratory of the senior author, and representative samples were retained for reference.

Results and Discussion

Whereas reports from previous field research by Adams and Clark (1958), as well as that by MacCulloch and Weller (1988) fail to mention the presence of algae on Long Point turtles, our studies have shown that all five turtle species collected during the recent project serve as substrates for *Basicladia*, which occurred in varying amounts ranging from minute tufts to patches. *Basicladia*

chelonum was collected from *Clemmys guttata*, *Emydoidea blandingii*, *Chrysemys picta marginata*, *Chelydra serpentina* and *Graptemys geographica*. *Basicladia crassa* was found only on *Chelydra serpentina*.

The collections of *Basicladia* from Pontiac County are the most northerly records for the genus, previously known from Maine and Michigan. *Basicladia* has also been reported from Japan (Yendo 1919; Yoneda 1952), China (Wang 1935, Gardner 1937), Australia (Ducker 1958), Mexico (Proctor 1958; Dixon 1960), and in Brazil and Iraq (McNeil, personal communication).

We also believe our report is the first of *Basicladia* from *Clemmys guttata*. That *C. guttata* is one of the least frequently encountered turtles of North America, particularly by phycologists, may contribute to the lack of a previous report of its hosting *Basicladia*. Ernst (1975, 1976) did not encounter *Basicladia* during his extensive survey of *C. guttata* in Pennsylvania, nor did Moski (1957b) report *Basicladia* as among the algae found on *C. guttata* in Connecticut. Ernst and Barbour (1972) do not mention the occurrence of any epizooic algae on *C. guttata*.

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Western Painted Turtles, *Chrysemys picta bellii*, Basking on a Nesting Common Loon, *Gavia immer*

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Gelatt, Thomas S., and Jill D. Kelley. 1995. Western Painted Turtles, *Chrysemys picta bellii*, basking on a nesting Common Loon, *Gavia immer*. Canadian Field-Naturalist 109(4): 456–458.

Repeated observations were made of Western Painted Turtles (*Chrysemys picta bellii*) basking on an occupied Common Loon (*Gavia immer*) nest and on top of an incubating loon at a lake in Minnesota. The tolerance behavior of the loons appeared abnormal as it has not been noted before and could be viewed as maladaptive. However, the behavior may be unusual but not abnormal and is indicative of the high level of nest attentiveness in Common Loons.

Key Words: Common Loon, *Gavia immer*, Western Painted Turtle, *Chrysemys picta bellii*, interspecific association, nest attentiveness, Garfield Lake, Minnesota.

In order that a specific behavior be termed abnormal, the normal repertoire must first be well known (Grier 1984). Fox (1968) stated that abnormal behavior is uncommon and maladaptive, but emphasized the importance of observing animals in their natural environment to establish the criteria of normality. Normal nesting behavior in Common Loons (*Gavia immer*) has been well described (Olson and Marshall 1952; Sjölander and Ágren 1972; McIntyre 1975) and causes of potential disturbance identified (Titus and VanDruff 1981). However, we could find no published references regarding an interspecific association as described here. This absence does not necessarily validate ours as atypical and we publish it in hopes of eliciting reports of similar observations.

Study Area and Methods

Garfield Lake, Hubbard County (47°079N, 94°529W), Minnesota, approximately 32 km east of Itasca State Park is a shallow (maximum depth 10 m), 374 ha, eutrophic lake with some emergent shoreline vegetation. The lake includes partly developed shorelines with private homes interspersed in forest. The two nest sites were about 100 m apart and built on artificial nesting platforms anchored in 2 m of water and surrounded by sedge (*Carex* spp.), cattail (*Typha* spp.), milfoil (*Myriophyllum* spp.), wildrice (*Zizania* spp.), bur-reed (*Sparganium* spp.) and pondweed (*Potamogeton* spp.). The wooden platforms were constructed from a 1 m^2 frame with a foam interior and covered with nesting materials left from previous loon nesting efforts. Loons, nests and turtles were observed periodically between 10 May and 15 July 1994 via a 10x spotting scope from a location of approximately 120 m from site 1 and 200 m from site 2. Motorized fishing and ski boats often cruised within 100 m of the platforms.

Results

A pair of Common Loons was first observed in the area on 24 April 1994, and in early May were seen displaying described nesting behavior of incubating postures and nest exchange (McIntyre 1975) on site 1. New nesting materials were already present. Site 2 was just below the water surface and only partially visible with no signs of recent nest construction. During the same time period, Western Painted Turtles (*Chrysemys picta bellii*) were first observed basking on the nest mound at site 1 with the incubating loon. During subsequent observations the turtles often occupied all of the remaining exposed space on the nest mound. On 17 May, 15 turtles were counted on the visible side of the nest. The incubating loon showed little or no apparent response to the movements of the turtles and on more than one occasion allowed turtles to climb onto and rest on its back. During one observation (see cover photograph) the loon was seen to peck at a turtle on its back; however, the turtle only moved slightly and did not retreat.

The nest was rarely vacated by both incubating adults and only once did we witness the nest vacant when turtles were present. During a recess when the incubating loon was approximately 10 m away from the nest, the turtles were seen moving forward toward the space vacated by the loon. Eggs were not visible from our observation point. However, the characteristic behavior and posturing of the loons (McIntyre 1975) suggested that at least one egg was present. Upon return to the nest to incubate we observed the loon moving turtles by kicking them backwards out of the nest cavity and waggling its body into place.

Turtles were seen basking primarily in the early morning and afternoons consistent with reported activity patterns (Ernst and Barbour 1989). It is unknown at what time the water level dropped enough to expose site 2 but turtles were also observed basking on the site 2 platform with no nest material present. Snapping Turtles (*Chelydra serpentina*) are known to be present in the lake but were never seen basking on the sites. Western Painted

Turtles and loons both continued to use the site 1 nest until the evening of 24 May, when a severe thunderstorm with winds >112 km/hour came through the area. The following day the loons were not seen and a portion of the nest appeared to have slid off the platform which was partially submerged. No shell fragments were found on the platform. Turtles continued to bask on the platform at site 1 and a minimum of 24 turtles was counted on one occasion.

A pair of loons suspected to be the same pair was observed and heard calling two days later in the area. On 30 May, a loon pair was seen on site 2 which was now fully exposed above the water line. The pair was observed pulling nest material onto the platform and copulating. On 1 June, an adult loon was seen on site 2 in apparent incubating posture surrounded by approximately 12 cm of new nesting material. A nest exchange (McIntyre 1975) was observed during the afternoon of 2 June. On 6 June two Western Painted Turtles were seen basking on site 2 with the incubating loon and turtles were later observed basking on the incubating loon at this site. During subsequent observations through the end of June turtles continued to use site 1 for basking and both turtles and loons used site 2.

No observations were made during the first two weeks of July and after 15 July, loons were no longer seen on site 2. An adult pair and two chicks were observed in open water near the nest sites shortly thereafter.

Discussion

Titus and VanDruff (1981) coined the term "stickers" for nesting loons which refused to leave the nest when moderately harassed, and found that their average brood size was greater than loons who flushed. Likewise, McIntyre (1975) identified nest attentiveness as "the major strategy for nest protection", and found that nesting pairs were attentive 99.1% of the time in undisturbed situations. If the loons we observed were indeed stickers despite boat traffic, shoreline disturbance and possibly previous nesting encounters with turtles, this could partially explain their tolerance to the turtles. Detailed studies of Common Loon nesting habits indicate that, when available, islands are preferred to the mainland as nesting sites (Olson and Marshall 1952; Vermeer 1973; McIntyre 1975; Titus and VanDruff 1981) suggesting avoidance against predation from terrestrial mammals (Olson and Marshall 1952; McIntyre 1975). In developed areas human-associated disturbance, including domestic animals along the shoreline, could also result in selection for loons nesting away from shore. Western Painted Turtles and nesting Common Loons share common terrestrial predators such as Raccoons (*Procyon lotor*) and Striped Skunks (*Mephitus mephitus*) (Snow 1982; McIntyre 1977; Olson and Marshall 1952) and would both benefit from basking or nesting on islands away from the mainland.

Basking in Painted Turtles is a routine well-developed behavior (Ernst and Barbour 1989) and serves not only a thermoregulatory function (Boyer 1965) but also may aid the turtles in elimination of parasites (Cagle 1950). Furthermore, Painted Turtles will seek out locations with the presence of vegetation or structures which can support them (Sexton 1959). Basking substrates are not limited to inanimate structures, as also noted by MacGeorge (1928 *in* Boyer 1965) who witnessed a freshwater turtle basking on the head of a water buffalo (*Syncerus caffer*). An ideal basking area also provides protection from wind and good escape cover (Cagle 1950) as do preferred loon nesting habitats (McIntyre 1988). Consequently, if loon nest sites are limited, loons may tolerate turtles on their nests rather than abandon a limited resource and risk reproductive failure. Such a risk may outweigh the potential for turtles inadvertently to break or puncture eggs or the energetic costs involved in continually removing turtles from the nest. An increase in activity on the nest as would be associated with constant turtle removal, could also make the area more conspicuous to avian predators. Finally, the strong drive required to hatch a brood successfully might be so overwhelming as suggested to explain interspecific feeding in birds (Shy 1982), that the relatively rare occurrence and low potential for disturbance is not selected against.

We suggest that the observed tolerance of this pair of nesting loons to turtle basking on them and their nest site represents an adaptive trait in an area depauperate of offshore nest sites.

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Cooperative Foraging by North American River Otters, *Lutra canadensis*

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Serfass, Thomas L. 1995. Cooperative foraging by North American River Otters, *Lutra canadensis*. Canadian Field-Naturalist 109(4): 458–459.

I observed four North American River Otters, suspected to be members of a family group, using a coordinated foraging strategy to capture fish in riverine habitat in northeastern Pennsylvania.

Key Words: River Otter, *Lutra canadensis*, cooperative foraging, Pennsylvania.

North American River Otters (*Lutra canadensis*) have developed various behaviors for capturing prey (Liers 1951; Meyerriecks 1963; Park 1971; Beckel 1990). However, with the exception of Sheldon and Toll's (1964) observation of two otters successfully foraging in a large reservoir in northcentral Massachusetts by schooling fish into a shallow cove, otters have not been reported to participate in coordinated hunts. The otter foraging strategy described by Sheldon and Toll (1964) resulted in fish being concentrated in a confined area, but there was no indication that either of the otters directed the fish toward its hunting companion. Beckel (1990) observed otters foraging in groups and reported no evidence of otters using coordinated hunting strategies.

While conducting livetrapping studies and other ecological investigations of River Otters in northeastern Pennsylvania during 1980-1982 (Serfass et al. 1986), I observed 11 otters engaged in foraging and other behaviors for 3 hours and 14 minutes. My most interesting observation occurred while checking otter live-traps at the Upper Tunkhannock Creek in northeastern Pennsylvania between 1001 and 1023 hours on 3 September 1981 when I observed four otters cooperatively foraging for fish. Initially, I detected a disturbance in the center of a large pool (approximately 30 m long, 10 m wide, and 1 m deep) while walking along a trail approximately 10 m from the streamside. I concealed myself behind a tree and observed otters congregated near the center of the pool. Shortly thereafter, the otters separated into pairs and swam to upstream and downstream ends of the pool. Simultaneously, the otters submerged and swam in a rapid, zig-zag pattern to the center of the pool, apparently herding fish before them. When the pairs converged, I saw schooled fish leaping from the water. Two of the otters were successful in capturing fish. One of the successful otters carried its fish beneath an undercut bank located on side of the stream where I was concealed and began to eat. As I approached the top of the bank, the otter detected me and abandoned the partially consumed fish. I retrieved the fish and identified it as a White Sucker (*Catostomous commersoni*) about 30 cm total length.

Based on time of year and solitary tendencies of non-familial otters (Melquist and Hornocker 1983), I'm confident the group of otters observed consisted of a family unit (adult female and offspring). Occurrence of a family group in the area was supported by capture of two juvenile otters (male and female) in a Hancock live-trap on 19 September

1981 approximately 300 m downstream from the site of my observation. Adult female otters have been reported to capture and provide prey to offspring participating in hunts (Rock et al. 1994; Sheldon and Toll 1964). The foraging behavior I observed probably developed while the juvenile otters transitioned from reliance on obtaining prey from the female parent to independent foraging. I suspect foraging success and development of hunting skills by juvenile otters is enhanced by group behaviors that concentrate prey.

Acknowledgments

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A Mallard, *Anas platyrhynchos*, Increase in the Maritimes: Implications to Black Ducks, *A. rubripes*

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During the 1980s it was apparent that Mallards (*Anas platyrhynchos*) were increasing in the maritime provinces of Canada where they had become a relatively widely distributed breeder. We analyzed historical (1965 to 1992) banding data from the Canadian Maritime Provinces to determine trends in Black Duck (*A. rubripes*), Mallard, and hybrid numbers. Despite increases in Mallard and hybrid numbers, Black Duck numbers have remained relatively stable.

Key Words: Mallard, *Anas platyrhynchos*, Black Duck, *Anas rubripes*, hybridization, bird banding, Maritimes.

Johnsgard (1967) concluded that the primary zone of sympatry between Black Ducks *Anas rubripes* and Mallards *A. platyrhynchos* had moved eastward approximately 500 km during the past century. He predicted that this trend would almost certainly continue. Johnsgard and DiSilvestro (1976) analyzed 75 years of data and reported that, by the mid-1970s, there were negligible numbers of Mallards in only the extreme northeast of Black Duck range. By the 1980s, it was apparent that Mallards were increasing in the Maritime Provinces of Canada, where they had become a relatively widely distributed breeder (Erskine 1992).

During much of the period of Mallard eastward expansion there was decline in Black Duck numbers where the two species were sympatric [1.6% annual rate of continental decline from 1962 to 1982 (U.S. Department of the Interior 1982, Final frameworks for late season migratory bird hunting regulations, 47 *Federal Register* 41252-41269, USDA, Fish and Wildlife Service, Washington, D.C., as cited by Feierabend 1984)]. Johnsgard and DiSilvestro (1976) speculated that the decline in Black Ducks was related to competition and hybridization with Mallards. Ankney et al. (1987) argued that the concomitant increase in Mallards in Ontario has been a

factor, perhaps the primary factor, causing the decline of Black Ducks there.

The aims of this study are to analyze historical banding data to determine trends in Mallard, Black Duck, and hybrid (Black Duck x Mallard) numbers in maritime Canada. Implications to Black Duck populations are discussed.

Methods

Banding records for the Maritime Provinces (New Brunswick, Nova Scotia, Prince Edward Island) were obtained from the National Bird Banding Office (Canadian Wildlife Service, Ottawa, Ontario). All banding records from 1965 to 1992, inclusive, were compiled to provide an index of annual population numbers. Records from 1965 onwards were used as 1965 was the first year a hybrid category appeared in the records. This was also the start of a co-operative banding program with greatly increased samples.

Data were analyzed collectively for the three provinces. Inconsistencies in identifying hybrids during the early years of the banding period casts some doubt on the reliability of the data. As a result, data covering the past 15 years were often analyzed separately because these data are considered the most reliable. The number of banding permits issued annually was used as an index of catch/effort variability. Regression analyses employed natural log transformations of bandings/banding effort to stabilize variance.

Results

In total, 82 799 Black Ducks, Mallards, and hybrids banded in the Maritime Provinces from 1965 to 1992 were used in the analysis (78 462 Black Ducks, 3309 Mallards, 1028 hybrids). Banding success was consistent among years with an average combined total of 2957 individuals banded annually ($n = 28$ years, $SD = 54.4$).

There was little variation in total duck bandings (Figure 1, top right). Although there was no significant increase in total ducks handled during the last 15 years ($r^2 = 0.096$, $p = 0.149$), minor increases are attributable to increases in Mallards and hybrids. Figure 1, bottom left, shows a significant increase ($r^2 = 0.664$, $p < 0.001$) in Mallard bandings, particulary in the last 15 years. However, absolute numbers remained low. There was a similarly slight increase in hybrids (Figure 1, bottom right) but absolute numbers remained low so that there was no significant increase ($r^2 = 0.034$, $p = 0.567$) during the past 15 years. As expected, the increase in hybrids was correlated with the increase in Mallards (Figure 2). Figure 1 (top left) shows that Black Duck numbers remained relatively stable during the entire period, including that of the greatest Mallard and hybrid increase (mid-1980s).

Discussion

The use of banding data to test hypotheses about trends in population numbers can be criticised. In the case of waterfowl banding in maritime Canada, there are several weaknesses in the standardization of data collecting. Often the number of ducks banded are a function of pre-set quotas or budget constraints; bait stations can operate at different times of year and may be shut down if numbers are low; bait station locations are not randomly set and may move from year to year; and, hybrid determination can be subjective and skills may have evolved since earlier years. Despite these weaknesses, we believe the information presented by these data, admittedly not perfect, can beused to illustrate meaningful long-term trends in population numbers.

Although the numbers of Mallard and hybrid bandings increased throughout the study period and particularly during the past fifteen years, the increases were small and absolute numbers of both remained relatively low (annual ranges: Mallards = 19 - 718, hybrids = 4 - 117). Regardless of these changes, Black Duck numbers remained stable, suggesting that Mallards were not causing a noticeable decline in Black Ducks in maritime Canada.

One alternate hypothesis is that Mallards have not yet reached a critical or threshold level — a point at which they would begin to impact Black Duck numbers negatively. A variation of this is that absolute Mallard numbers are still sufficiently low that their negative impact on Black Ducks is undetectable at this time, especially given the inherent variability of the data.

Seymour (1992) showed that competitive superiority and exclusion can result in Black Ducks being displaced by Mallards. However, this did not appear to prevent Black Ducks from breeding on his study area at current densities. D'Eon et al. (1994) showed a low (2%) rate of hybridization on their study area that had one of the highest densities of Mallards in the Atlantic region. Even there, there was no evidence that Mallards were extending their range outward from this point of concentration into Black Duck breeding habitat.

Perhaps at current Black Duck and Mallard densities there is adequate breeding habitat for Black Ducks to avoid Mallards. Alternatively, there may be species isolating mechanisms that reduce the impact of Mallards on Black Ducks. Nevertheless, at current Mallard densities, Black Ducks in maritime Canada appear to be remaining stable despite Mallard increases.

Acknowledgments

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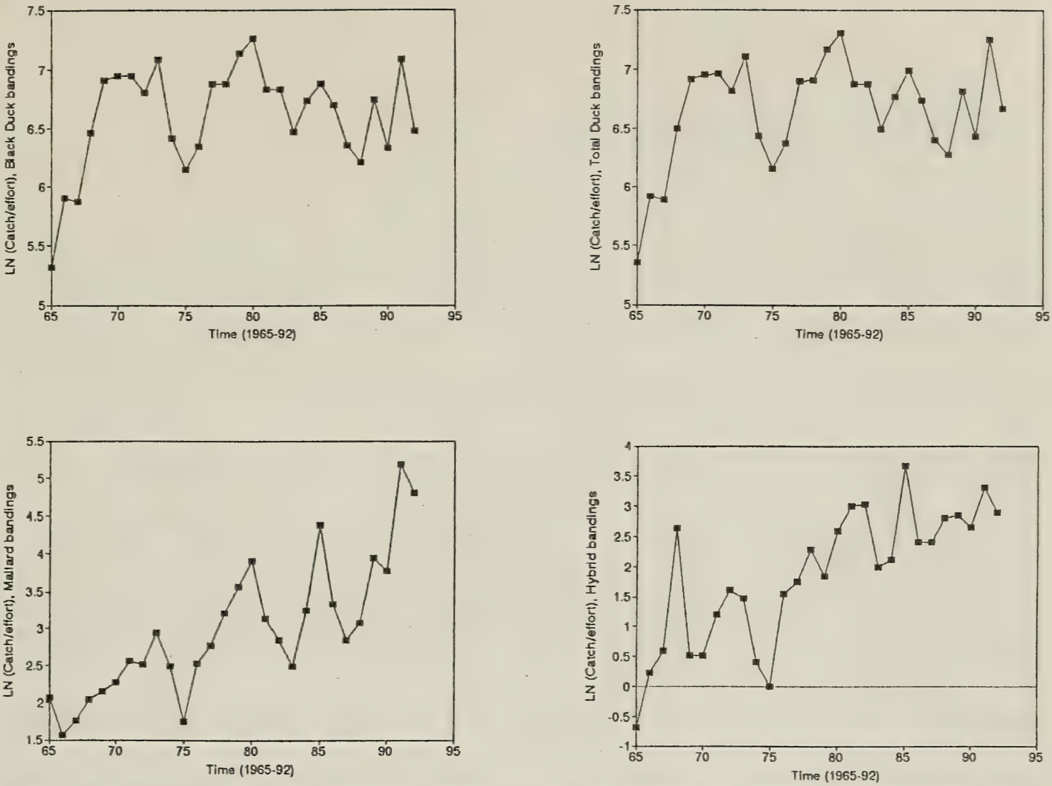

FIGURE 1. Annual catch (number of individuals banded) to effort ratios from 1965-1992 for Black Ducks (top left), Mallards (bottom left), hybrids (bottom right) and for all combined (top right), in the Canadian Maritime Provinces (from Canadian Wildlife Service banding records).

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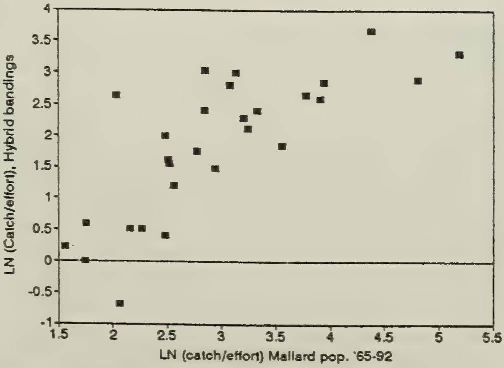

FIGURE 2. Mallard versus hybrid annual catch to effort ratios from 1965-1992 in the Canadian Maritime Provinces (from Canadian Wildlife Service banding records).

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The Distribution and Abundance of the Gulf of St. Lawrence Aster, *Aster laurentianus*, in Prince Edward Island National Park

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In 1992 and 1993, Prince Edward Island National Park conducted surveys to determine the abundance and distribution of the Gulf of St. Lawrence Aster (*Aster laurentianus*) in the Park. The Gulf of St. Lawrence Aster is a vulnerable plant species (COSEWIC Status). Approximately 75 000–80 000 Gulf of St. Lawrence Aster plants were located during these surveys, numbers that substantially exceed previous estimates of the plant abundance in Prince Edward Island National Park.

Key Words: Gulf of St. Lawrence Aster, *Aster laurentianus*, Prince Edward Island National Park, distribution, abundance.

The Gulf of St. Lawrence Aster, *Aster laurentianus*, historically has been reported around the Gulf of St. Lawrence in New Brunswick, Magdalene Islands and Prince Edward Island, occurring in moist sandy soils near brackish and saline marshes and along the edges of ponds and streams (Fernald 1950). Houle and Haber (1990) reported an estimated total fewer than 1000 Gulf of St. Lawrence Aster plants at 13 sites throughout its known eastern region, and only 12 individual plants occurring in Prince Edward Island National Park. The plant has been given vulnerable status by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Prince Edward Island National Park conducted an extensive survey for Gulf of St. Lawrence Aster in 1992 and 1993 as part of its ongoing resource management and monitoring efforts for vulnerable and endangered species.

Methods

In 1992 and 1993, sites in P.E.I. National Park were surveyed where the Gulf of St. Lawrence Aster had previously been reported (Houle and Legault 1986, unpublished report PEI National Park). In addition to re-surveying these sites, other areas in the Park were evaluated for their potential to provide suitable habitats for Gulf of St. Lawrence Aster based on habitat descriptions provided in Fernald (1950) and Houle and Haber (1990). Thirteen sites were surveyed for the Gulf of St. Lawrence Aster during the flowering and seed dispersal stage of development from September to early November in this study (Figure 1). A large number of Gulf of St. Lawrence Asters were observed along the Blooming Point area of the Park. Since a total count of plants in this area was not practical, numbers of plants were estimated by conducting a total count of plants in a 25 cm x 25 cm quadrat then extrapolating the density to the approximate area of coverage. The total count in the sample quadrat was conducted on a quadrat considered having typical or representative plant density for the area of coverage.

Results

Six sites are now known where the Gulf of St. Lawrence Aster occurs in Prince Edward Island National Park as a result of this study. The three sites along Blooming Point were not previously surveyed for the plant. The discrepancy in the current estimated number of plants in the Park compared to previous counts reported by Houle and Haber (1990) can be attributed to the Blooming Point area that was not surveyed prior to this study. Table 1 lists the six sites in the Park and the number of plants either individually counted or estimated to occur at each site. The results of this study indicate that the distribution and abundance of the Gulf of St. Lawrence Aster in Prince Edward Island National Park substantially exceeds previously reported estimates by Houle and Haber (1990).

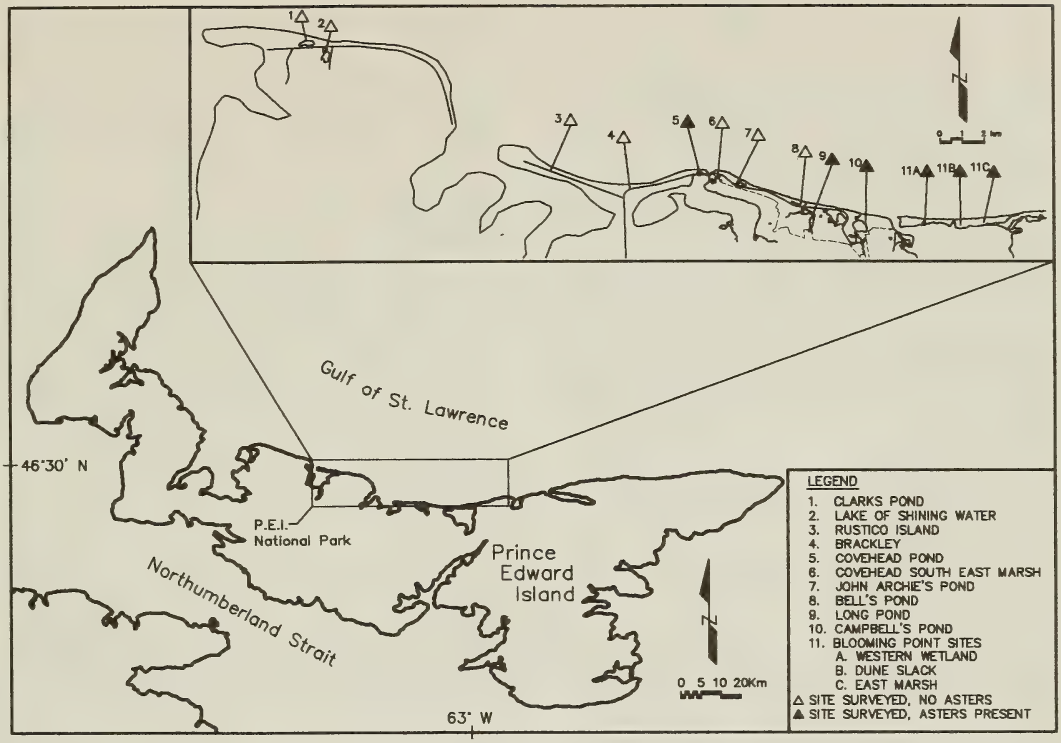

FIGURE 1. Location map showing areas in Prince Edward Island National Park where the Gulf of St. Lawrence Aster occurs.

Discussion

The scope of the study reported in this publication was simply a survey on the distribution and abundance of this plant species for Park management purposes. The reader should refer to Hinds (1986) and Houle and Haber (1990) for detailed descriptions of the plant and specific details on the ecology and overall distribution of the plant.

The obvious factor that contributed to an overall increase in abundance of this plant species in the Park is attributed to locating large populations on Blooming Point, an area that was not previously surveyed. Although the abundance and distribution of annual plant species can vary depending on climatic variables, the casual factors that may affect interannual variation were not investigated in this study. The numbers of plants in the two Blooming Point sub-populations, Dune Slack and Eastern Marsh, were estimated based on a typical average count of several 25 cm x 25 cm quadrats and extrapolated to

TABLE 1. Numbers of Gulf of St. Lawrence Asters Counted or Estimated in Prince Edward Island National Park, 1992-1993.

Locality[1]	Number of Plants	
	1992	1993
Covehead Pond, Queen's County	164	214
Long Pond, Queen's County	1	1
Campbell's Pond, Queen's County	30	3
Blooming Point, Queen's County		
Western Wetland	425	0
Dune Slack	15-20 000 (est)	15-20 000 (est)
Eastern Marsh	48-60 000 (est)	48-60 000 (est)

[1]Detailed site descriptions are provided in P.E.I. National Park (unpublished report, under Contract Number P.E.I. 92–007).

the area of plant coverage. Plant coverage in these two sub-populations were relatively uniform and the estimate is intended only to provide Park management staff with information that considerable numbers of the plant occur in an area not previously surveyed. Houle and Haber (1990) reported, in a summary of the distribution and abundance of the aster, that 12 plants occurred at Brackley Beach, near the type locality. No plants were located at the type locality in this study due to the fact that the locality was eliminated through development by the Park.

Evaluation of Status

Based on the results of this study the current COSEWIC vulnerable status for this plant should be reviewed.

Acknowledgments

This study was funded by Prince Edward Island National Park under contract number PEI 92-007. The assistance of Ms. Dianne Griffin in identifying suitable habitat and the various life stages of the Gulf of St. Lawrence Aster is gratefully acknowledged. Hal Hinds also confirmed the identification of the Gulf of St. Lawrence Aster.

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Observations of Agonistic and Mutualistic Interactions between Birds and Non-avian Vertebrates on the E. S. George Reserve, Michigan

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Nagle, R. D., R. C. van Loben Sels, and J. D. Congdon. 1995. Observations of agonistic and mutualistic interactions between birds and non-avian vertebrates on the E. S. George Reserve, Michigan. Canadian Field-Naturalist 109(4): 464–466.

Only two interactions between birds and non-avian vertebrates, other than direct acts of predation and mobbing behaviors, were observed during an 18-year turtle study on the University of Michigan's E. S. George Reserve. The first involved a pair of Gray Catbirds (*Dumetella carolinensis*) that attacked a Blue Racer (*Coluber constrictor*), and the second observation involved a White-tailed Deer (*Odocoileus virginianus*) that appeared to solicit cleaning activities from a male Red-winged Blackbird (*Agelaius phoeniceus*).

Key Words: Blue Racer, *Coluber constrictor*; Catbird, *Dumetalla carolinensis*, cleaning behavior, interspecific encounter, mutualism, nest defense, Red-winged Blackbird, *Agelaius phoeniceus*, White-tailed Deer, *Odocoileus virginianus*.

Because most organisms live in environments inhabited by other species, interspecific encounters are unavoidable. Interspecific encounters include the general categories of competition, predator-prey, territorial or nest defense, parasitism, and mutualism. The frequency of some of these interactions is probably higher in nature than published observations imply, and variation in the response of an organism to an interspecific encounter may have important consequences in survivorship and reproductive success.

From 1976 to 1993 we conducted a study of nesting ecology of three species of turtles. Each year four to seven people were in the field from 0600 until after dark daily between mid-May and early July. As a result we have logged a minimum of 11 observer-years in the field on the University of Michigan's E. S. George Reserve near Pinckney, Michigan. Over the 18-year period, only two instances of birds interacting with non-avian vertebrates, other than those categorized as direct acts of predation and mobbing behaviors, were observed. The first involved a pair of Gray Catbirds (*Dumetella carolinensis*) that attacked a Blue Racer (*Coluber constrictor*), and the second observation involved a White-tailed Deer (*Odocoileus virginianus*) that appeared to solicit cleaning activities from a male Red-winged Blackbird (*Agelaius phoeniceus*).

Gray Catbird — Blue Racer Interaction: At approximately 1600 hours on 27 June 1985, we (RCvLS and JDC) made the following observations with and without the aid of binoculars. For approximately 7 min two Catbirds attacked a Blue Racer (approximately 1.5 m total length) as it crossed an open firelane. We were approximately 20 m away when our observations began, and neither the birds nor the snake appeared to be aware of us. As the snake moved under a Black Cherry tree (*Prunus serotina*), the Catbirds both swooped down over the snake and called loudly. When the snake attempted to turn back from crossing the firelane, its head was in the grass while its posterior one third was on the firelane. One of the Catbirds landed on the ground, approached the posterior of the snake, pecked it and flew away. The snake responded by rapidly bringing its head around toward its tail and reversing the direction of movement. Each time the snake was in a position in which its head appeared to be obstructed from the birds' view, one or both birds would land and attack the snake's tail area. During the encounter there were six or more peckings observed. The snake became more agitated as the attacks continued and eventually moved rapidly into the old field and went under a Juniper (*Juniperus virginiana*). Both birds followed the snake and landed near the Juniper, where they stayed for about 3 minutes and then left in the direction of the firelane. Catbirds nest in Michigan during June; however, we failed to locate a Catbird nest at this site.

Aristotle's (*see* Creswell 1978) suggestion that nest-defense behavior of female birds increases the survival of young has eventually led to explanations of such behavior in evolutionary terms under the framework of life-history and parental investment theories (Montgomerie and Weatherhead 1988). That the birds behaved in a way that reduced their exposure to the snake's head suggests that: (1) the Catbirds recognized the snake as a potential predator, and (2) the birds recognized the head as the dangerous part of the snake. In addition, because of the high probability of mortality associated with mistakes in recognizing the head of a snake, the behavior is most likely evolved rather than learned. The Catbirds' snake-attack behaviors appeared to be as complex as threat displays (Brunton 1986) and broken wing injury displays (Gochfeld 1984) reported for Killdeers.

Red-winged Blackbird — White-tailed Deer Interaction: At approximately 1030 hours on 21 June 1993 we (RDN and JDC) observed a male Red-winged Blackbird perched on the head of a White-tailed Deer. The following sequence of interactions took place over an 8 min period. Neither animal indicated that they were aware of our presence as we watched through binoculars from the top of a hill about 30 m away. At first it was not apparent that the bird was doing anything except using the head of the deer as a perch. However, we watched the bird move about the deer's head and peck at what appeared to be dark spots. Areas of the head that were pecked included those around the eyes, muzzle, back of the neck, and particularly the area at the base and inside of both ears. At no time did the bird perch on the back or flanks of the deer. Although the deer remained relatively motionless during cleaning, pecks to the inside of the ears sometimes evoked vigorous head-shaking and ear movements by the deer.

The most remarkable aspect of the interaction was that which followed the deer's head shaking. Four times the head shaking by the deer became vigorous and resulted in the blackbird leaving the deer. Three times the blackbird perched on nearby bushes and the deer slowly approached the blackbird with its head lowered and its ears positioned horizontally to the ground. The approach ended when the blackbird returned to the deer's head and resumed pecking. At the end of the fourth encounter, the bird flew away and the deer continued to forage along the edge of the marsh.

Instances in which birds remove food from large animals have been reported for over two thousand years, and whether the observations represent mutualism or simply opportunism by the bird has been the subject of much debate. In 459 B.C. Herodotus (Book 2, Chapter 68; as cited in Howell 1979) observed a bird called the Trochilos pick leech-like parasites from the gaping jaws of Nile Crocodiles (*Crocodylus niloticus*), a behavior observed by Brehm (1879, as cited in Howell 1979) in the Egyptian Plover (*Pluvianus aegyptius*). Other notable examples of birds that clean non-avian vertebrates include the Small Ground Finch (*Geospiza fuliginosa*) that grooms Marine Iguanas (*Amblyrynchus cristatus*; Amadon 1967), Common Grackles (*Quiscalus quiscula*) that harvest leeches from Map turtles (*Graptemys*; Vogt 1979), Wattled Jacanas (*Jacana jacana*) that clean Capybaras (*Hydrochoerus hydrochaeris*; Marcus 1985), and the Redbilled Oxpecker (*Buphagus erythrorhynchus*) that removes ticks and other ectoparasites from at least 21 species of African ungulates (Stutterheim 1981).

Our observation of the Red-winged Blackbird apparently removing and eating parasites from the head of the White-tailed Deer on the E. S. George Reserve was certainly interesting in itself. However, the active participation of the deer in eliciting the bird's participation strongly suggested that the interaction was mutualistic. The Southern Stingray's (*Dasyatis americana*) "solicitation pose" elicits cleaning from the Bluehead Wrasse (*Thalassoma bifasciatum;* Snelson et al. 1990), although measurable benefits do not always indicate a selective

advantage to the stingray and other hosts in similar symbiotic relationships (Gorlick et al. 1978).

Active participation of the animal being cleaned by a bird have not been reported, although Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*) may respond to the calls of Scrub Jays (*Aphelocoma coerulescens*) in relation to cleaning activities (Isenhart and Desante 1985). In North America, cleaning of ungulates by birds has been observed most frequently in corvids (Scrub Jays, Isenhart and Desante 1985; Schulz and Budwiser 1970: California Jays (*Aphelocoma californica*), Dixon 1944; and Black-billed Magpies (*Pica pica hudsonia*), Linsdale 1946). Isenhart and Desante (1985) suggested that learning capabilities necessary for development of mutualistic cleaning interactions with large mammals require a high level of intelligence that is common to corvids. However, we report such behavior in the Red-winged Blackbird, an icterid, and suggest that either the level of intelligence necessary for development of mutualistic cleaning behavior has been underestimated in birds other than corvids, or the level of intelligence that is required to develop mutualism is common to the cleaned animal (the deer) rather than the bird.

The 11 observer years spent in the field during the 18 years of the turtle study resulted in just two observations of birds interacting with non-avian vertebrates in behaviors other than those categorized as direct acts of predation and mobbing behaviors. The low frequency of such observations may have resulted in part from our focus on turtle nesting. However, anyone who has made observations on turtle behavior can attest that this type of study presents numerous opportunities for observing things other than turtles. Therefore, we conclude that the low frequency of observations made during the turtle study result from behaviors that are difficult to observe due to their short duration, and their relative rarity. However, the low frequency of observations alone should not be considered a measure of the potential importance of the behaviors to the animals involved. A single nest saved from a predator may represent a substantial portion of a bird's lifetime reproductive success. The removal of ectoparasites from a deer may reduce local inflammation and sites where initiation of infection could occur. The energy harvested by cleaning a deer may represent a major part of Red-winged Blackbird's daily energy input, a food source which may be particularly important during a period of high energy demand such as the reproductive season.

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Internal Parasites of Sympatric Bison, *Bison bison*, and Cattle, *Bos taurus*

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Bison (*Bison bison*) and Cattle (*Bos taurus*), though closely related, are ecologically different, so we hypothesized that they would differ in prevalence of disease-causing organisms. We compared internal parasites of sympatric Bison and Cattle in the Henry Mountains, Utah, by screening feces for parasites. We identified five taxa of parasites (*Eimeria bovis, E. zuernii, Fasciola hepatica*, order Strongylida, *Trichuris* spp.). Prevalences differed between Bison and Cattle, especially those parasites associated with water. Likely causes are differences in host suitability and ecological differences between Bison and Cattle that affected the probability of transmission.

Key Words: Bison, *Bison bison*, Cattle, *Bos taurus*, parasites, disease, Utah.

Bison (*Bison bison*) once numbered in the tens of millions and roamed throughout much of North America (Roe 1970). Indiscriminate slaughter during the 1800s resulted in near-extinction; by 1900, only a few hundred Bison remained. Intensive efforts narrowly averted extinction, and numbers recovered to about 100 000 (Dary 1989). Most Bison today, however, are confined by fences on wildlife refuges or are intensively managed on private lands for commercial purposes; only a handful of herds are free-ranging.

Bison carry diseases that also may occur in domestic Cattle (Tessaro 1989), and controversies have arisen about the possibility of disease transmission between free-ranging Bison and neighboring Cattle in several localities, including Utah (Popov and Low 1950; Nelson 1965), Yellowstone and Grand Teton National Parks (Thorne et al. 1991), and Wood Buffalo National Park (McCormack 1992). Although Bison and Cattle are similar in many respects, information on diseases of Cattle cannot necessarily be extrapolated to Bison (Tessaro 1989); indeed, the host-disease relationship in Bison differs markedly from that of Cattle (Meagher and Meyer 1994; Meyer and Meagher 1995). Further, ecological and behavioral differences between Bison and Cattle may affect disease transmission (Meagher and Meyer 1994). For example, when Bison and Cattle occur in the same area they may forage in different localities because of differing responses to forage availability, slope, and distance to water (Van Vuren 1982).

Bison harbor a variety of disease-causing parasites that also occur in Cattle (Tessaro 1989). Our objective was to compare prevalences of internal parasites in sympatric, free-ranging Bison and Cattle in the Henry Mountains, Utah. Bison and Cattle differed in local distribution; in particular, Cattle were more closely associated with water (Van Vuren 1982). We hypothesized that prevalence of internal parasites would differ between Bison and Cattle, especially parasites associated with water.

Methods

The Henry Mountains (38°5′N, 110°50′W), Garfield County, rise above the deserts of the surrounding Colorado Plateau to a maximum elevation of 3540 m. The lower slopes are about 1800-2400 m elevation and support extensive Pinyon Pine (*Pinus edulis*) and juniper (*Juniperus* spp.) woodlands. Large areas of these woodlands have been mechanically cleared and seeded to exotic forage species, chiefly Crested Wheatgrass (*Agropyron desertorum*) and Alfalfa (*Medicago sativa*). The climate is arid; annual precipitation in pinyon-juniper woodlands averages only about 25-40 cm. Surface water is scarce and is available only at a few widely scattered springs and small streams (Nelson 1965). Our study was conducted in the upper drainages of Sweetwater and Bullfrog creeks, on the western slope of the Henry Mountains.

The Henry Mountains have been used as summer range by Cattle since the late 1800s. In recent years most Cattle grazing has occurred in and near areas that have been cleared and seeded. Bison were introduced in the 1940s, and the herd currently numbers several hundred. Although the Bison range widely, they frequently graze in areas that are also grazed by Cattle, especially cleared and seeded areas on the western slopes of the mountains (Van Vuren and Bray 1986); the two species sometimes feed within 20 m (Van Vuren 1982). Bison are migratory and spend winters primarily in the deserts to the west and southwest (Van Vuren and Bray 1986). Our study area was located at intermediate elevations that are used by Bison year-round. Cattle graze from June to October, then are moved to lower elevations where Bison usually do not occur. The Cattle from which

fecal samples were obtained had not been treated for parasites for two years prior to this study. The Bison had never been treated for parasites, and a screening of feces from eight Bison in 1962 revealed no parasites (Nelson 1965).

During 8-12 September 1993 we collected one fresh fecal sample from each of 51 Bison and 44 Cattle. We usually did not have sufficient time to determine age class or sex because most Cattle and all Bison were wary and stampeded when approached. About 20 g of fecal material were collected from the center of each fecal deposit and preserved by mixing with 60 ml of 10% formalin (Foreyt 1986). Samples were stored 150-200 days before analysis.

Fecal samples were screened for the presence of parasites using floatation, sedimentation, and trichrome stain procedures (Brown and Neva 1983; Georgi and Georgi 1990). Parasites were floated using saturated zinc sulfate, then detected by light microscopy at 45x. For sedimentation, 10% formalin was added to the fecal sample, then parasites were detected by light microscopy at 45x. Material from each of the sedimentation samples was smeared on two coverslips using polyvinyl alcohol, then stained using trichrome stain; each coverslip was scanned for 5 minutes under a light microscope at 100x. Ova, oocysts, and trophozoites were identified with the aid of Georgi and Georgi (1990). A three-way contingency table (Sokal and Rohlf 1981) was used to determine if parasite prevalence differed between Bison and Cattle.

Results

Five parasite taxa were identified, *Eimeria bovis*, *E. zuernii*, *Fasciola hepatica*, order Strongylida, and *Trichuris* spp. (Table 1); all five can cause diseases in Cattle (Georgi and Georgi 1990). Two of the parasites identified (*E. bovis* and *E. zuernii*) were found only in Cattle feces, one (*Trichuris* spp.) was found only in Bison feces, and two (Strongylida and *Fasciola hepatica*) were found in feces of both Bison and Cattle (Table 1). Prevalences were low except for Strongylida, which occurred in 51% of Bison feces (Table 1).

TABLE 1. Prevalence (%) of parasites in fecal samples from free-ranging Bison (n = 51) and Cattle (n = 44) in the Henry Mountains, Utah.

	Bison	Cattle
Protozoa		
Eimeria bovis	0	5
E. zuernii	0	7
Trematoda		
Fasciola hepatica	4	14
Nematoda		
Strongylida	51	16
Trichuris spp.	4	0

Parasite prevalence differed between Bison and Cattle; we rejected the null hypothesis that for a given parasite taxa, host species and prevalence were independent (G = 26.8, df = 5, P < 0.001). Twenty-three percent of Cattle feces contained *Eimeria bovis*, *E. zuernii*, or *F. hepatica*, compared with only 4% of Bison feces (G-test of independence, G = 8.1, df = 1, P < 0.005).

Discussion

The high prevalence in Bison feces of Strongylida is consistent with results from Yellowstone National Park, where 80% of Bison examined carried *Strongylus* spp. (Zaugg et al. 1993). The low prevalence of *Fasciola hepatica* and *Trichuris* spp. in Bison also is consistent with other studies (Locker 1953; Zaugg et al. 1993). No protozoans were found in Bison feces, an unexpected result because both *Eimeria bovis* and *E. zuernii* were common among Bison in Montana (Penzhorn et al. 1994).

As predicted, parasite prevalence differed between Bison and Cattle. One cause may be differing host-parasite relationships. Bison and Cattle, although closely related (Wall et al. 1992), differ substantially in genetics (Cronin and Crockett 1993), metabolism (Christopherson et al. 1978), digestive physiology (Schaefer et al. 1978), and rumen microbial populations (Towne et al. 1988); perhaps they also differ in suitability as hosts for parasites.

We suggest that ecological and behavioral differences also are important. Bison and Cattle mostly use different winter ranges, and they may have acquired different parasites accordingly. Morever, although they occur in the same general area during summer, Bison and Cattle in the Henry Mountains exhibit pronounced differences in local distribution (Van Vuren 1982). Cattle are relatively sedentary and graze primarily on gentle slopes near water. Bison, in contrast, roam widely and often graze localities that are on steep slopes, far from water, or both (Van Vuren 1982). Because internal parasites often are transmitted on ingested food, differences in foraging ecology between Bison and Cattle may affect transmission. Further, Cattle are more closely associated with water than are Bison (Van Vuren 1982). Life cycles of three of the parasite taxa identified require relatively mesic or even aquatic environments; transmission of *Eimeria bovis* and *E. zuernii* is promoted by high levels of moisture in the environment (Kheysin 1972), and the intermediate host of *F. hepatica* is an aquatic snail (Georgi and Georgi 1990). Prevalence of these parasites was significantly higher in Cattle than in Bison.

Disease transmission between Bison and Cattle has been demonstrated in closely-confined situations (Davis et al. 1990). But, because some ecological differences cannot be expressed in confinement,

such evidence has uncertain relevance to free-ranging animals. Bison and Cattle are different species, and their internal parasites differ accordingly. Perhaps ecological differences can be exploited to reduce disease transmission between Bison and Cattle.

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Prebasic (Postnuptial) Molt in Free-ranging Harris' Sparrows, *Zonotrichia querula*, in the Northwest Territories, Canada

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Harris' Sparrows (*Zonotrichia querula*) in the Northwest Territories, Canada, in 1989-1991, were single-brooded, although they occasionally replaced a clutch if the loss occured prior to hatching. Harris' Sparrow breeding chronology is highly synchronized, and the fledging period for first nests was 3-14 July. Of 21 adult Harris' Sparrows captured on or after 3 July, no bird captured prior to 13 July was molting: estimated dates for prebasic molt initiation in 10 birds captured after beginning molt ranged from 13 to 18 July. The almost complete separation of the nestling phase and molt initiation support the idea that most Harris' Sparrows at my study site did not begin prebasic molt until after their young fledged. This is similar to most passerines breeding at high latitudes, including White-crowned Sparrows (*Zonotrichia leucophrys*). However, my results contradict results of previous workers who found that caged Harris' Sparrows exposed to natural photoperiods found on their breeding grounds initiated prebasic molt at the time when breeding Harris' Sparrows should be feeding nestlings. This difference may be attributed to earlier use of birds which had not participated in the reproductive cycle.

Key Words: Harris' Sparrow, *Zonotrichia querula*, molt, Northwest Territories.

Prebasic molt in passerines breeding at high latitudes generally is of relatively short duration, with little overlap between molt and breeding activities (Stresemann and Stresemann 1966; Farner 1983). For example, duration of prebasic molt decreases with latitude in species such as the White-crowned Sparrow (*Zonotrichia leucophrys*), ranging from 83 days at 35°N to 48 days at 65°N (Morton et al. 1969; Mewaldt and King 1978). Onset of prebasic molt does not occur in Alaskan populations of *Z. l. gambelii* until after young have fledged, and molt is restricted to the period between the end of reproductive activities and the beginning of fall migration (King et al. 1965; DeWolfe 1967; Morton et al. 1969). However, DeGraw and Kern (1990) reported a diferent pattern of prebasic molt in Harris' Sparrows (*Zonotrichia querula*), which breed in the forest tundra-transition zone of northern Canada, from about 57°N to 69°N (Godfrey 1986). They studied prebasic molt using caged birds captured during fall migration near Omaha, Nebraska, and exposed to photoperiods comparable to those found on their breeding grounds (ca. 60°N) beginning in mid-May (DeGraw and Kern 1990). Prebasic molt lasted about 82 days in individual Harris' Sparrows, and the timing of molt initiation in captive birds suggested overlap between breeding activities and prebasic molt in wild Harris' Sparrow populations (DeGraw and Kern 1990). Given the difference between molt patterns found in captive Harris' Sparrows and in *Z. leucophrys* breeding at high latitudes, observations on prebasic molt in free-ranging Harris' Sparrows should be of interest. In this note I report on initiation of prebasic molt in Harris' Sparrows breeding in the Northwest Territories (NWT), Canada, using data gathered during studies of the species' breeding biology (Norment 1992).

Study Site and Methods

I studied Harris' Sparrow breeding biology at Warden's Grove (WG), NWT, Canada (63°41′N, 104°26′W) 21 May-23 July 1989, 27 May-21 July 1990, and 24 May-17 July 1991. Previous observations also were made in August and September 1977. I examined molt in birds captured in Potter traps or mist nets, or collected for stomach content analysis, between their arrival on the breeding grounds and 20 July, by which time all known nesting pairs had fledged young (Norment 1992). For comparative purposes, I scored molt using the system used by DeGraw and Kern (1990) for Harris' Sparrows, with each molting primary feather, secondary feather, or rectrix assigned a score of one point. Body and crown molt were assigned one to three points, depending on the intensity of molt. Maximum possible molt score for an individual was 54 points. I used shedding intervals and feather growth rates in DeGraw and Kern (1990) to estimate the date of prebasic molt initiation in birds examined after they had begun molting. Breeding chronology was determined by monitoring the fate of 18 nests in 1989, and 23 nests in both 1990 and 1991; this represented 75% of the breeding pairs in my study area in 1989, and 85% of the breeding pairs in 1990 and 1991 (Norment 1992).

Results and Discussion

Harris' Sparrow breeding chronology was highly synchronized during all three years of the study; range

of fledging dates for first nests was 4-11 July in 1989, 4-14 July in 1990, and 7-13 July in 1991 (Norment 1992). Harris' Sparrows at WG are single-brooded, but may occasionally replace a clutch if the loss occurs prior to hatching. I observed one confirmed instance of replacement nesting, following loss of a clutch on 18 June 1990. Late clutch dates (after 20 June) and mate guarding and precopulatory displays when most pairs were feeding nestlings suggested that replacement nesting also occurred occasionally in 1989 and 1991 (Norment 1992). Harris' Sparrow nesting chronology at WG was very similar to that at Churchill, Manitoba, where most fledging occurs prior to 12 July (Semple and Sutton 1932; Rees 1973).

I examined 21 adult Harris' Sparrows during the fledging period for first nests, which ranged from 3 to 14 July over the 3-year study period (Figure 1). The range of estimated dates for prebasic molt initiation in 10 birds captured after beginning molt was 13-18 July, with a median date of 15 July (Figure 1). Highest observed molt score was 3, for male and female birds collected on 20 July 1989, and in none of the birds examined did I note that molting had progressed beyond the third primary (P3). It is possible that my estimates of molt onset dates for individual Harris' Sparrows were somewhat inaccurate, due to use of shedding intervals observed in captive birds (DeGraw and Kern 1990). However, shedding intervals for primaries in Alaskan *Z. leucophrys* average less than intervals reported for caged Harris' Sparrows (Morton et al. 1969). This suggests that, if anything, I underestimated dates of molt initiation, and that molt was initiated in Harris' Sparrows at WG slightly later in the season than I report here.

Because it was difficult to trap birds after 1 July, and I was unwilling to collect banded birds from my immediate study area, the nesting status of individual birds examined after 10 July was unknown. However, the almost complete separation of the nestling phase of the nesting cycle and molt initiation (Figure 1), and the behavior of collected birds, most of which appeared to be feeding fledged young, support the idea that most Harris' Sparrows at WG do not begin prebasic molt until after the young have fledged. Separation of breeding activities and molt in free-ranging Harris' Sparrows conflicts with the data of DeGraw and Kern (1990), who found that prebasic (postnuptial) molt began on 28 June-15 July (average = 5 July) in their population of caged birds, well within the nestling stage of the nesting cycle for Harris' Sparrows at Churchill (Rees 1973; DeGraw and Kern 1990).

Some overlap between nesting activities and prebasic molt at WG may have occurred in those few birds involved in replacement nesting. For example, the eggs in the one known replacement nest did not hatch until 8 July. Although the nest was subsequently depredated, an average nestling period of 9.26 d (Norment 1992) means that nestlings would have been present in the nest on 17 July, when most Harris' Sparrows examined had begun molting (Figure 1). Detailed studies of molt dynamics in a population of Mountain White-crowned Sparrows (*Z. l. oriantha*) in California showed that there is no fixed relationship between the termination of reproduction and onset of molt, and that prebasic molt and reproductive activities may overlap, particularly for birds nesting late in the season (Morton and Morton 1990; Morton 1992).

Little is known about duration of prebasic molt in free-ranging Harris' Sparrows, other than that the process is completed prior to their arrival on the northern Great Plains between late September and mid-October (Swenk and Stevens 1929; DeGraw and Kern 1990). Some Harris' Sparrows remain at WG until early September; late date for the species in 1977 was 9 September (Norment 1985), although few birds were seen after 30 August (Norment, unpublished data). Because in 1989-1991 I did not remain at WG until Harris' Sparrows departed, I was not able to determine the molt status of late-summer birds. However, if adult Harris' Sparrows complete prebasic molt before migrating southwards, as is generally true for *Z. l. gambelii* in Alaska (DeWolfe 1967; Morton et al. 1969), and if prebasic molt is not initiated until around 15 July, then duration of prebasic molt in free-ranging Harris' Sparrows should be approximately 45 d, much less than the 82 days reported by DeGraw and Kern (1990).

Reasons for differences between my data on prebasic molt and those of DeGraw and Kern (1990) are unclear. Caged birds supposedly replicate the pattern of prebasic molt in free-ranging *Zonotrichia* (Morton

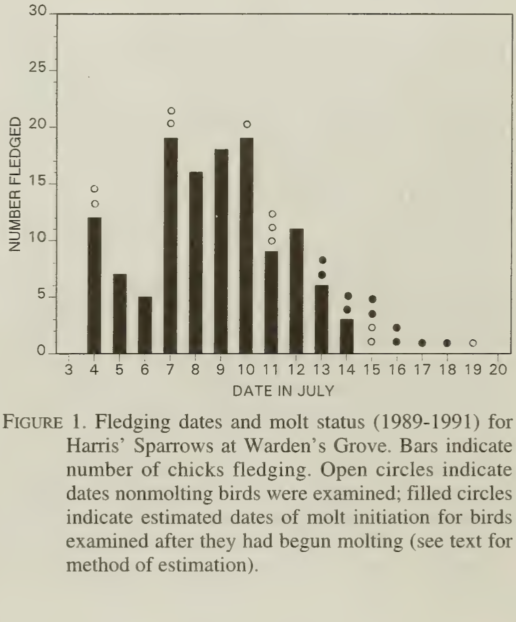

FIGURE 1. Fledging dates and molt status (1989-1991) for Harris' Sparrows at Warden's Grove. Bars indicate number of chicks fledging. Open circles indicate dates nonmolting birds were examined; filled circles indicate estimated dates of molt initiation for birds examined after they had begun molting (see text for method of estimation).

et al. 1969; King 1972; Morton and Welton 1973; Mewaldt and King 1978). However, with the exception of Mewaldt and King (1978), who held birds at a location within the general breeding range for *Z. leucophrys*, individuals in the studies mentioned above were held captive on the breeding grounds, and thus subjected to environmental conditions very similar to those experienced by wild birds. Additionally, these birds had been reproductively active and had undergone full gonadal development (Martin Morton, personal communication). Seasonal changes in photoperiod appear to be the main environmental cue affecting the timing of molt (Payne 1972), although other factors, including temperature (Chilgren 1978) and nutritional status (Murphy and King 1991), also may influence molt dynamics in *Zonotrichia*. Mean date for onset of prebasic molt in *Z. l. oriantha* in California varied by 17 days across eight consecutive field seasons (Morton and Morton 1990), suggesting that other factors beside photoperiod, including ambient temperature and precipitation, may influence molt initiation in this population (Morton 1992). Thus molt dynamics in captive Harris' Sparrows kept in Nebraska (DeGraw and Kern 1990) may have been affected by exposure to a combination of environmental factors not present on the breeding grounds. Furthermore, these birds had not participated in the reproductive cycle. Results of the current study and those of DeGraw and Kern (1990) suggest that more work on comparison of molt dynamics in captive and free-ranging birds is needed, especially for birds held in localities other than the breeding grounds. Also, examination of free-ranging birds prior to their departure from the breeding grounds would help establish length of prebasic molt in Harris' Sparrows.

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Summer Movements and Behavior of an Arctic Wolf, *Canis lupus*, Pack without Pups

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A pupless arctic Wolf pack (two adults, three yearlings) studied 5-30 July 1993 on Ellesmere Island, Northwest Territories, traveled nomadically around an area $\geq$ 381 km^2, but the alpha pair sometimes left the yearlings at a rendezvous site. All pack members hunted Arctic Hares. The alpha pair sometimes fed the yearlings, the alpha male doing so more than the alpha female.

Key Words: Wolf, *Canis lupus*, pack, Arctic Hare, *Lepus arcticus*, hunting behavior, provisioning, den.

Summer movements and behavior of most Wolf (*Canis lupus*) packs generally are characterized by individual pack members traveling to and from the pack's current den or rendezvous site where the pups are left; the adult pack members hunt and bring food back to the pups (Murie 1944; Mech 1970, 1988; Carbyn 1974; Ballard et al. 1991). Because most Wolf packs produce pups each year, little is known about Wolf-pack movements and behavior when no pups are present. The following observations of a pup-free arctic Wolf pack were made 5-30 July 1993 in the Eureka area of Ellesmere Island, Northwest Territories, Canada (80° N, 86° W). This pack was habituated to the author and observed each summer from 1986 through 1994 (Mech 1988, 1994, 1995; Packard et. al 1992).

When the alpha female of this pack was first seen on 5 July 1993, from a distance of 2 m, no nipple development was observed, contrary to all other years (i.e., 1986-1992) when the pack had pups (Mech 1995). None of the dens previously occupied in the area (Mech and Packard 1990; Mech 1988, 1993) exhibited any fresh digging or other signs of use during the current year.

In 1992, this pack consisted of only an alpha pair and three pups which survived at least through early August (Mech 1995). During the 1993 study, the alpha pair was accompanied by three smaller individuals (two females and a male) which I judged as yearlings. Two of the 1992 pups had been highly habituated to the author, and one had been less habituated. Of the three putative yearlings in 1993, two were highly habituated and one was less so, providing evidence that these three animals were the 1992 pups, as expected.

The pack or its members were observed for 188 hours in 1993 while they were resting, sleeping, traveling, and hunting. Their movements could best be described as nomadic during this period, for they did not center around a den. However, the pack often used a traditional rendezvous site within about 1.6 km of a weather-station garbage dump. The three yearlings tended to remain together during travels (at about 8.3 km/hr, Mech 1994) and when resting and sleeping; often they slept in contact. Their greetings of the alpha male, especially "licking up," were much more intensive, excited, and prolonged than those when greeting the alpha female. The yearlings spent a great deal of time hunting Arctic Hares (*Lepus arcticus*), usually 1-2-kg leverets, and tended to do the scouting and chasing, whereas the adults tended more to lie on promontories and wait for the hares to run by as the yearlings chased them. The yearlings also caught a few lemmings (*Dicrostonyx groenlandicus*) and nestlings.

Of the 12 occasions when I observed the pack at the rendezvous site during 5-24 July, the Wolves left the site as a pack five times. Twice, the alpha pair left the yearlings at the rendezvous site, once for 4.5 hours and once for $\geq$ 32 hours. During the former occasion, only the alpha female returned after 4.5 hours (see below); she and the three yearlings left the site together 24 hours later, apparently before the alpha male had returned. The alpha male did return 24 hours after the rest of the pack had left the site, and he remained there for $\geq$ 2 hours but eventually left.

During the five other times when I observed the Wolves at the rendezvous site attempting to leave, the alpha pair tried to depart, but the yearlings would not follow and began howling; the adults then stopped for several minutes, howled, and returned to the yearlings or stopped and slept. My distinct impression was that during these times the alpha pair wanted to travel, but the yearlings did not, so the alpha pair relented.

Once (16 July 1993) when the alpha pair left the yearlings, I followed the pair 9.5 km on an all-terrain vehicle (Mech 1994). The alpha male then dug up a cached front shoulder of a Muskox (*Ovibus moscha-*

tus) calf. The alpha male delivered the item to the alpha female who ate it for 10 minutes and returned to the yearlings. The yearlings had temporarily split up, but I did observe the alpha female regurgitating to the male yearling near the rendezvous site.

Four times when the pack was observed hunting Arctic Hares, the alpha male ambushed the leverets being chased by yearlings and killed the hares. Three of these times he either immediately dropped the leveret in front of the yearling and the yearling consumed it, or he quickly relinquished it when the yearling approached; once, described below, he gave it to a yearling after 45 minutes of apparently waiting to give it to the alpha female.

The alpha female, however, seldom fed the yearlings. She did not participate as much in the hunts as the alpha male, and she only caught two hares while I watched. One of these times she ate at least part of the hare, and another time she kept a hare from a yearling for several minutes, although in both cases yearlings did manage to wrest part of the hares from the female. On 12 July I gave the alpha female a 4-kg piece of seal to see whether she would feed it to the yearlings, but she ate and guarded it for 4 hr + 40 minutes until most of the meat was gone from the bone. The yearlings begged, groveled, and wheedled much of this time, and the alpha female finally relinquished the bone to one of them. This difference between the frequency and readiness with which the alpha male and alpha female fed the yearlings may explain why the yearlings mobbed and licked up to the alpha male more than to the alpha female. Ballard et al. (1991) found that an alpha male provided more food for pups during summer than did the alpha female.

On 13 July, the five Wolves traveled to the area around the pack's traditional den (Mech 1988; Mech and Packard 1990) and hunted hares for 6 hours nearby. The alpha female visited the den at 2200 hours and lay nearby but eventually headed back 0.5 km to the area where the rest of the pack were hunting hares. Once when the alpha male killed a leveret, he carried it to the den as if to give it to the alpha female. He looked around the den for several minutes and kept the hare away from the yearlings which kept trying to get it. When the alpha female did not return after 45 minutes, he relinquished the leveret to one of the begging yearlings.

During this same observation, the alpha male and yearling male slept around the den from 0030 to 1220 hours, and the other three pack members from 0440 to 1220 hours on 14 July. From 0329 to 0439 hours, the alpha female entered the den six times for periods of 7-19 minutes each and dug out the den several times. At 1220 hours, the pack left the den and began traveling again until I lost them at 1430 hours, some 21 km travel distance away from the rendezvous site and about 13 km from the den.

This pack was known to use an area of ≥ 1600 km^2 (Mech 1988), and during this study, they ranged over ≥ 381 km^2. Based on the directions the Wolves were heading when I lost sight of them, the directions from where they reappeared, and their nearby travel routes and ranges known from previous years (Mech 1995), they probably used an area ≥ 670 km^2 and possibly much more.

Several generalizations can be made about the behavior of this pupless Wolf pack. The pack generally traveled nomadically over much of their range as packs usually do during winter and as pupless Wolf packs in forested areas also do (Mech unpublished). Second, the social cohesion of the pack seemed at least as great during this period as it was when the pack had a den and pups. Third, the yearlings sometimes behaved like pups in remaining together in a rendezvous site while the alpha pair hunted for many hours and delivered food to them. The latest reported use of a rendezvous site until this study was when the pups were about 32-weeks old (Mech 1970: 143). Fourth, lacking pups, the alpha pair invested their time and food in the yearlings. When pups are present, the yearlings are more independent in obtaining their own food, often deliver food to the pups, and are denied food by the adults (Mech 1988).

Acknowledgments

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Fates of Translocated Cougars, *Felis concolor*, in Alberta

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Ross, P. Ian, and Martin G. Jalkotzy. 1995. Fates of translocated Cougars, *Felis concolor*, in Alberta. Canadian Field-Naturalist 109(4): 475–476.

Three Cougars in Alberta were translocated in response to problem-wildlife complaints. One, an adult female, died within a few weeks. The other two, subadult males, survived at least 10 months and did not return to their natal areas.

Key Words: Cougar, *Felis concolor*, problem wildlife, translocation, Alberta.

Livestock depredation and other problem wildlife complaints in western North America have historically been dealt with by animal damage control agencies by destruction of the offending individuals or entire populations (Connolly 1978). In Alberta, as in most jurisdictions, Cougars (*Felis concolor*) have been subject to lethal predator control in response to complaints regarding losses to personal property (Gurba and Neave 1973).

Recently, however, a general softening of opinion toward predators (Hancock 1980) as well as lack of public support for traditional predator control have resulted in attempts to deal with individual problem animals by nonlethal means. At present, most complaints regarding Cougar predation on livestock and pets in Alberta are responded to by attempts to capture and translocate the offending individuals (Alberta Fish and Wildlife Division 1992). However, the efficacy of translocations of Cougars has not been documented as it has with other large predators including Wolves, *Canis lupus* (Fritts et al. 1985), Brown Bears, *Ursus arctos* (Miller and Ballard 1982) and Black Bears, *U. americanus* (Rogers 1986). We report on the case histories of three Cougars which were translocated following depredations in southwestern Alberta.

Depredation complaints were reported or referred to problem wildlife specialists of the Alberta Fish and Wildlife Services (AFWS). Officers contracted the services of houndsmen, and dogs were released at the scene of the depredations. Cougars were treed and immobilized, then transported to a selected site and released. The three Cougars captured and translocated had been previously marked with either a radio collar or ear tag as part of an investigation of Cougar population characteristics and food habits. Fates of these animals were determined by recovery of these marks.

An adult female Cougar, F31, was implicated in an attack in which two domestic sheep were killed. She had been radio collared as a kitten 16 km west of the depredation site, and was 4.3 years old. On 7 December 1988 she was captured at the scene and was moved 51 airline km south and released. We radio-tracked her from an aircraft at approximately weekly intervals. For three weeks she remained very close to the release site, then began moving south. On 21 March 1991 she was found dead on a ridgetop 35 km south-southeast of the release site. Telemetry data suggested she may have died as early as 20 January. Her intact carcass weight of 30.0 kg was 73% of her live weight one year earlier. A pathological examination determined that proximal cause of death was an unidentified bacterial infection, to which she was predisposed due to her extremely malnourished condition (N. R. Lowes, Alberta Agriculture, personal communication). No injuries directly related to her capture were noted.

At the time of the depredation, F31 was accompanied by a 20-month-old son, M48. One week after the original complaint, M48 killed a goat at another farm 1 km from the first, and was captured on 15 December 1988. He was released at the same site as his mother. Because M48 was eartagged only, his movements could not be followed. On 2 December 1989, in response to a complaint of Cougar depredation on two goats, AFWS officers captured M48 on a farm 79 airline km south of his release site. He was taken a further 43 km south and released adjacent to

Waterton Lakes National Park. His subsequent movements are unknown.

An independent 15-month-old male, M60, was captured after he killed a dog in a ranch yard. He was translocated 63 km to the north-northwest on 8 March 1989. He was shot by a licenced hunter 20 km from the release site on 4 January 1990. He was in good physical condition at that time.

These data suggest that translocation may be an effective alternative to destruction of nuisance Cougars, particularly with subadult animals. Homing ability appears not to be well-developed in Cougars, because Cougars released within 51 km of their home ranges did not return. Two of three translocated Cougars, both young males, survived the experience although one subsequently reoffended. Both presumably adapted to a diet of natural prey. The effects of translocation for juvenile and subadult male Cougars may duplicate those of natural dispersal, a typical event in the lives of this sex and age class (Ross and Jalkotzy 1992). In Utah, one adult male Cougar returned to his home range after translocations of 56 and 72 km, whereas one subadult male and two adult females did not return from distances <57 km (F. G. Lindzey, Wyoming Cooperative Fish and Wildlife Research Unit, Laramie, personal communication).

The sole adult female moved died soon afterwards. Possibly the social stresses of injection into unfamiliar, occupied Cougar habitat prevented her from hunting successfully, rendering her susceptible to physiological trauma. Nonetheless, she was given a chance not offered by more traditional animal damage control methods. We encourage problem wildlife personnel to consider translocating depredating Cougars, and monitoring their fates through radiotelemetry.

Acknowledgments

We thank Fish and Wildlife Officers from districts in southwestern Alberta, and in particular Jan Allen, for handling Cougars and forwarding information. N. R. Lowes, Alberta Agriculture, Animal Health Division, performed the necropsy. Ralph Schmidt helped in the field and Gary Erickson arranged funding for aircraft charter.

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First Record of Offshore Spawning for the Black Rockfish, *Sebastes melanops*

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Welch, D. W. 1995. First record of offshore spawning for the Black Rockfish, *Sebastes melanops*. Canadian Field-Naturalist 109(4): 477–479.

Two female Black Rockfish (*Sebastes melanops*) were caught in the central Gulf of Alaska near Ocean Station Papa (50°N, 145°W) in March 1992; the gonads of one contained eyed embryos and the second was ripe and running. This is the first confirmed record of offshore pelagic spawning by the species, and the greatest distance offshore at which it has been found. The offshore distribution of *S. melanops,* which includes a shallow water benthic juvenile phase, is therefore more extensive than previously thought.

Key Words: Black Rockfish, *Sebastes melanops*, spawning, Gulf of Alaska, Pacific Ocean.

Adult Black Rockfish, *Sebastes melanops*, are widely distributed over the continental shelf at depths < 200 m (Dunn and Hitz 1969) from Baja California to Alaska (Miller and Lea 1972). There are four previously published catch records for *S. melanops* caught in the open North Pacific; one spent and three gravid females (Dunn and Hitz 1969) (Table 1). However, despite the collection of larvae and pelagic juveniles individuals as far as 266 km offshore (LaRoche and Richardson 1980), there appear to be no records of spawning Black Rockfish reported from the offshore.

During offshore research on the oceanic distribution of Pacific salmon, I captured two Black Rockfish in surface gillnets. Both contained eyed larvae in the ovaries. These records are unusual because of the general paucity of information on the biology of *S. melanops*, and because they appear to be the first firm evidence of the actual time and place of spawning for this species in the open North Pacific.

Occurrence and Species Identification

The two Black Rockfish, both female, were caught in surface gillnets during research operations to examine the offshore distribution of Pacific salmon (Table 1). The first female (52.4 cm FL; 2060 g) was caught at Ocean Station Papa and contained firm gonads containing eyed embryos; the weight of both gonads combined was 42 g.

The second female (51.4 cm FL; 2308 g) was caught further to the south, and was ripe and running when brought on board; embryos were extruded on deck with little or no pressure to the belly (Figure 1). The larger of the two ovaries, which appeared to be nearly full, weighed 63.5 g; the right ovary was flaccid and partly empty.

Both fish were frozen at sea, and the preliminary identification made at capture was confirmed ashore. Identification was based on the following characteristics found on both fish (brackets indicates value for larger specimen, if different). Body colour: black shading to dusky-white on belly; peritoneum silvery-white with dark blotches. Fin rays: Dorsal XIII, 15; anal III, 9; pectoral 19; pelvic I, 5; gillrakers on first gill arch 33 (32). Examination ashore provided the following confirmatory information on the identification of the larger specimen: Head spines: nasal — weak, overgrown by skin; preocular, supraocular, postocular, tympanic, parietal, nuchal, coronal, suborbitals all absent. Opercular spines: one, sharp and stout; cleithral and supracleithral overgrown by skin; lachrymal one, stout and sharp. Frontal and parietal head ridges absent; interorbital space smooth and strongly convex; symphysial knob weak and rounded; anterior profile of anal fin vertical to slight anterior slant. Both fish had empty stomachs at the time of capture. They have been deposited at the Royal British Columbia Museum, RBCM 995-13-1 and RBCM 995-14-1.

Discussion

Pelagic larvae of *Sebastes melanops* have been recorded along the coastal shelf of Oregon from April to June, although the benthic juveniles have apparently only been recorded from the nearshore, chiefly in waters < 20 m depth (LaRoche and Richardson 1980). Landing data from commercial trawlers suggest that adult *S. melanops* also have a preferred depth distribution in waters <54m deep (Niska 1976). The capture of two female Black Rockfish near Ocean Station Papa, more than 1000 km offshore (Table 1), is therefore of interest because it substantially extends the known limits of the offshore distribution, and the capture of one female in ripe and running condition clearly establishes the existence of offshore spawning.

All six reported cases of *S. melanops* occurring in the offshore North Pacific have been female. All captures occurred in the spring in the surface layer (< 10 m). Most offshore records of *S. melanops* are from surface gillnet operations using salmon gillnets,

TABLE 1. Comparison of offshore occurrences of the Black Rockfish, *S. melanops*. All fish were captured with surface gillnets or longlines, within 7 m of the surface.

Latitude	Longitude	Distance Offshore (km)	Sex	Gonad Condition	Date of Capture	Standard Length (cm)	Water Temperature (°C)	Reference
50°N	145°W	1056	♀	gravid; eyed embryos	5 March 1992	52.4	6.0°	This study
45°18′N	140°56′W	1166	♀	ripe and running	11 March 1992	51.4	9.1°	This study
50°N	165°W	445	♀	spent	15 February 1969	38.3	3.8°	Dunn and Hitz 1969
45°37′N	125°04′W	89	♀	gravid	12 January 1963	Unknown	9.8°[a]	Dunn and Hitz 1969 Turner and Aro 1968
51°N	135°W	278	♀ (two)	gravid	13 January 1964	Unknown	7.6°[a]	Dunn and Hitz 1969 Turner and Aro 1968

[a]Temperature data from information recorded in data files held at the Pacific Biological Station, Nanaimo, B.C. See Turner and Aro (1968) for an overview of this data.

which typically have a 13.3 cm (5.25″) stretched mesh. It is unclear whether the failure to collect males represents a differential depth distribution for the sexes or simply random chance (probability < 2%). *S. melanops* collected from coastal areas off California are sexually dimorphic, with males slightly smaller than females at maturity (length at 50% maturity: males: 36 cm; females 41 cm; Wyllie Echeverria 1986, 1987); however, both sexes should be susceptible to capture by the gear used.

The vast majority of offshore salmon research in the past occurred during the summer, so the capture of *S. melanops* only in the spring suggests that they enter the near surface layer for spawning, and are distributed at depths > 10 m for the rest of the year. As the females contain zygotes, there is no need for males to be present at spawning.

The records of surface temperature, size of fish, and gonad condition (Table 1) suggest that spawning occurs at temperatures of ca. 9°C or higher. For the

FIGURE 1. Photograph of second female Black Rockfish (*Sebastes melanops*), showing ripe and running condition at capture.

central Gulf of Alaska, these temperatures are reached from early February to March, depending on latitude, but may not be attained until late June in the northern Gulf of Alaska.

Reported parturition times for *S. melanops* range from January-May off north-central California (Wyllie Echeverria 1987), and February to April off British Columbia (Westrheim 1975; Hart 1973), consistent with our offshore observations. Taking the average gestation period of 37 days at 10°C for *S. melanops* (Boehlert and Yoklavich 1984), if fertilization happened on the continental shelf and the females then proceeded directly offshore to spawn on the shortest path to the collection sites (and thus swimming directly against the prevailing current), then they would have had to travel at a minimum speed of 31.3 cm/sec, or ca. 0.6 body lengths/second, disregarding currents. Such swimming speeds are close to the optimal one body length/second values of directed swimming.

As the prevailing on-shore current velocity in the area of Station Papa is on the order of 50 cm/sec (Dodimead and Pickard 1967), or one body length/sec, and since spawning certainly occurs in nearshore waters, the required swimming speeds needed to reach the capture locations suggest that mating in *S. melanops* probably also occurs off the continental shelf as well as in inshore regions. The alternative interpretation, that some fish having a strongly directed offshore migration after insemination, is inconsistent with our knowledge of the coastal biology of *S. melanops*, the swimming speeds needed to reach the vicinity of Station Papa, and the occurrence of substantial numbers of spawners in coastal waters.

Adult *S. melanops* are preferentially distributed at depths of 8-55 m (Niska 1976), with a benthic juvenile stage following a pelagic larval period that extends for some 4-6 months (LaRoche and Richardson 1980). As pelagic larvae of *S. melanops* have previously only been collected as far offshore as 266 km (the maximum extent of larval surveys; LaRoche and Richardson 1980), the offshore distribution of *S. melanops* may therefore be more extensive than previously thought. This would be consistent with past speculation that at least some species of *Sebastes* have much more extended offshore distributions than current data would indicate (Moser and Boehlert 1991), and raises the interesting question as to whether offshore spawning by these individuals can contribute to the overall reproductive success of the population.

Acknowledgments

I thank Mr Graham Gillespie, Pacific Biological Station, for assistance with confirmation of the species identification, and the detailed examination of the larger female reporting on the structure of the head spines.

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News and Comment

Erratum: *The Canadian Field-Naturalist* 109(2)

Sabourin, André and **Roger Perreault.** 1995. Henry Mousley and the orchids of southern Québec. Canadian Field-Naturalist 109 (2): 273–281.

On page 276, it was reported: Both the *Aplectrum* and *Cypripedium* were very rate in Canada and *Tipularia discolor* was confined to western Canada. The real text is: The *Aplectrum* was very rare in Canada, the *Cypipedium* confined to western Canada and Mingan Islands, and the *Tipularia* unknown in Canada.

ANDRÉ SABOURIN

Grants for Conservation Biology Research in Minnesota

The Minnesota Natural Heritage and Nongame Research Program is solicting proposals for projects to be conducted during the 1996 and/or 1997 field seasons (or longer). Proposals should be for work contributing to the conservation and management of nongame wildlife (vertebrate or invertebrate), native plants, and plant communities in Minnesota. High priority will be given to projects focusing on specified topic areas, and on state endangered, threatened, or special concern species and rare natural communities. Awards average $3000 per year, but requests up to $10 000 per year will be considered. The deadline for submitting proposals is 19 January 1996. Decisions will be announced no later than 1 March 1996. This program is supported by contributions to the Minnesota Nongame Wildlife Tax Checkoff, Minnesota State Parks Nature Store Sales, and the Minnesota Chapter of The Nature Conservancy. For program guidelines, proposals format, list of priority topic areas, E&T species list, and other information, please contact: RICHARD J. BAKER, Natural Heritage and Nongame Research Program, Minnesota Department of Natural Resources, Box 7, 500 Lafayette Road, St. Paul, MN 55155-4007; phone: 612-297-3764; fax: 612-297-4961; e-mail: richard.baker@dnr.state.mn.us.

CITES Control List Number 11 (1995)

The latest update of the CITES Control List, dated May 1995, is available from the office of the Administrator, CITES, Environment Canada, Ottawa, Ontario K1A 0H3. It contains all species requiring import or export permits by virtue of listing on Appendices I, II, III. The list is by taxa, and gives scientific and English and French common names, with introductory explanatory material. It includes all listings updated by shaded new additions of taxa and appendix number as adopted by the Conference of the Ninth Meeting at Fort Lauderdale, USA, from 7 to 18 November 1994.

The Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement which regulates trade in a number of species of animals and plants, their derivatives, and any article made from them. The Convention is applied in Canada in accordance with a General Export Permit and a General Import Regulations, respectively, of the Export and Imports Act.

This list of CITES regulated species is an extract from both the:

Export Control List, amendment P.C. 1995-758 (SOR/95-236), dated 9 May 1995;

Import Control List, amendment P.C. 1995-757 (SOR/95-235), dated 9 May 1995;

published in the *Canada Gazette*, Part II, Volume 129, Number 11, dated 31 May 1995.

The Export and Import Permits Handbook may be purchased from: Publishing Centre, Supply and Services Canada, 45 Sacre-Coeur Boulevard, Hull, Quebec K1A 0S9.

FRANCIS R. COOK

The Canadian Endangered Species Protection Act: A Legislative Proposal

This slender booklet is 18 pages English and 18 pages French and bears the caution on the reverse of the title page that it is "for discussion only" and the stress that "It does not represent a decision by the Government of Canada with respect to proposals for endangered species legislation. It is the governments' strong hope that Canadians, individually or through their representative organizations, will consider the proposal carefully and offer specific suggestions for improvement".

The proposed act is concerned with legalizing a structure at "arm's length from government" with mechanisms for designating elements of the native fauna and flora of Canada at most risk of being eliminated. The encouragement of protection in Canada has been the concern since 1975 of the Committee on Status of Endangered Wildlife in Canada (COSEWIC) which has functioned, and largely functioned well, as a group constituted of federal, provincial and non-governmental representatives reporting to the Federal-Provincial Wildlife Directors annually. The proposed legislation would largely perpetuate COSEWIC in law.

However, whereas the current voting members of COSEWIC are working federal, provincial and non-governmental society employees appointed by their organizations, plus scientific chairmen largely but not exclusively drawn from these ranks, the legislation proposes a committee of Canadians "who have expertise in endangered species management with a knowledge of conservation biology, population dynamics, taxonomy, systematics or genetics." Committee members would be appointed by "federal, provincial, and territorial Ministers" not to represent particular parts of the country or society sectors but rather on the basis of their expertise. It is vaguely asserted that there will be "Mechanisms for ensuring that the best available candidates for appointment are nominated for consideration." Neither what these mechanisms might be, nor the number of members, nor the level of logistic or financial support to be given them, if any, are specified.

Whereas status has been given in the past on the basis of scientific evidence, the legislation would expand this to being "on the basis of the best available scientific, community, aboriginal, and traditional knowledge and information". Also disquieting are clauses specifying sweeping exemptions such as for "Activities related to the heritage of Canada's aboriginal peoples"; "Lawful activities that incidently harm a federally listed species"; and "Activities undertaken as part of the implementation of other federal legislation".

The Canadian Society of Zoologists and the Canadian Nature Federation have alerted their memberships to the limited scope of the legislation which has no provisions for habitat protection, without which simply designating species could arguably be ineffectual.

Naturalists and conservationists are urged to obtain, read carefully, and comment on the proposals in this proposed legislation. It is published by the Minister of Supply and Services Canada, 1995 by the authority of the Minister of the Environment Catalogue No. CW 66-143/1995 (ISBN 0-662-61973-0). Opinions should go to the MInister of the Environment, House of Commons, Room 509-S, Centre Block, Ottawa, Ontario K1A 0A6; or Endangered Species Conservation, Canadian Wildlife Service, Ottawa, Ontario K1A 0H3.

FRANCIS R. COOK

Book Reviews

ZOOLOGY

Top Birding Spots in Southern Africa

By Hugh Chittenden. 1992. Southern Book Publishers, Halfway House. 421 pp.

It is said that the two best-selling books in the Republic of South Africa are the Holy Bible, and Robert's *Birds of Southern Africa*. It is not surprising, then, that the southern African region has a wealth of well-documented birding sites of interest to globetrotting birders. Chittenden's compilation of submissions by local experts on the best sites south of the Zambezi is essential material for anyone anticipating a trip to the region. This volume provides good information for every country in the sub-continent except Mozambique, where until very recently civil war had raged for decades.

The book is organised as a set of checklists, with brief descriptions of endemic and specialty species likely to be found at each. A sketched map and brief description provide directions to the site, and a short paragraph describes the setting and provides information on habitat, accessibility, and other bits of information. Entries for each site have been prepared by local authorities who are credited at the foot of each section.

Checklists are restricted, for the most part, to 150 species. For a few sites, this covers everything recorded to date. For some, it permits presentation of less than half of the full list. In cases where only partial lists are possible, the local authorities have attempted to present the species most likely to be seen at the site.

There are a few errors in the text, but none that I have encountered has been critical. The most annoying, to date, is a typographic error in the entry for Walvis Bay, Namibia, that cost us a few minutes of head scratching and map comparing at the side of a deserted road in the middle of nowhere. It gives a distance of 10 km to Rooibank, the prime site for seeing the endemic dune lark. If you happen to be headed there, it is considerably farther than 10 km down the road, but since there is nothing else along the way, you will have no trouble figuring out when you have arrived.

This book is about birds, and just birds. It does not provide general information about the countries or the localities presented. However, there are other comprehensive sources for this sort of information in the region, and it is consequently not missed as it would be in a similar book for other parts of the world. A useful addition for those planning on travelling independently is a list of organisations and individuals, including phone numbers, from whom more detailed information may be sought.

Top Birding Spots in Southern Africa is recommended by the Southern African Ornithological Society.

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The Amphibians and Reptiles of Maine

Edited by Malcolm L. Hunter, Jr., John Albright, and Jane Arbuckle. 1992. Bulletin 838, Maine Agricultural Experiment Station, University of Maine, Orono, Maine 04469. 188 pp., illus. U.S. $9.95.

A colleague of mine in the 1970s was fond of declaring that Maine was the least known area herpetologically of all Canada. Though politically incorrect, this statement was a true reflection of the biogeographic lacuna, the lack of published data on distributions in the state, thrust between the growing information for Quebec and New Brunswick, and the irritant that this lack posed to a fuller understanding of amphibian and reptile ranges between these provinces. The long-awaited appearance of *The Amphibians and Reptiles of Maine* goes far toward filling this long-standing gap.

This important publication is the result of the Maine Amphibian and Reptile Atlas Project (MARAP) that began in 1984 in response to a need to know what vertebrate animals should be listed in the state's new Endangered Species Act and the obvious lack of sufficient data on this for amphibians and reptiles. It was supported by a variety of organizations (the Natural Heritage Program of the Nature Conservancy, the Maine Audubon Society, and the University of Maine Wildlife Department) with the assistance of the Endangered and Nongame Wildlife Fund of the Maine Department of Inland Fisheries and Wildlife. Over 250 volunteers responded to a call for participation. It was terminated in 1988 except for a continuing request for reports of the rarest species.

A Preface which outlines the history of the project and lists all the participants precedes an Introduction to Amphibians and an Introduction to Reptiles, followed by Maine's Environment as Habitat for Amphibians and Reptiles, a Checklist of Maine Amphibians and Reptiles, and a section explaining The Range Maps. Following are species by species accounts of 9 salamanders, 9 frogs, 7 freshwater and 3 marine turtles, and finally, 10 snakes. A concluding section covers Finding and Conserving Amphibians and Reptiles and includes, as well as the heading topics, comments on Hypotheticals, Accidentals, and other Oddities, Methods (of the Atlas Project) and Distribution and Abundance. Appendices cover Literature Cited, a Glossary, and a plea for more information.

Species accounts are uniform: an introductory paragraph placing the species in context with historical comments, and sections giving Description (and Voice for frogs), Taxonomic Status (where there is a subspecies or other problem) Distribution and Status, Habitat, Reproduction, Diet, and Interactions with People and Other Animals. Specific statements and examples are frequently referenced to the literature cited, making them easy to check. Observations by account author or others are carefully distinguished and credited. Each account has a black-and-white drawing of an adult, and sometimes additional ones usually illustrating variants, larvae, young, eggs, or key characters. There is a map of Maine with the atlas grid superimposed and each block where a record exists shown by its status — either based on a specimen or photograph, an individual handled but released, or one only observed or heard. An additional map depicts the entire North American range of the species. Each species account is individually authored and credited. The drawings are by Mark McCullough, and are generally excellent, sometimes superb, and rarely, particularly for the snakes, disappointing. A problem with the latter is that to save time (I assume) scalation is indicated by crosshatching rather than exact scale representation; although generally identifiable, this produces inferior representations; ie, the water snake on page 134 looks more like a bloated Milk Snake for much of its length (though the smaller comparative one on page 133 is accurate), the Brown and Redbelly snakes are also particularly poor (pages 141, 144) and the garter snakes (pages 150, 153) are somewhat disappointing; though, because of the great variation in these, are the most forgivable.

Problems in the texts are relatively few. Complexes like the Blue-spotted and Jefferson salamanders are carefully explained. Cory R. Etchberger in the Painted Turtle account, however, has a peculiar comment about subspecies "overlapping" that one might expect in literature from the 1930s, not in the 1990s. The problem of the Maritime Garter Snake and Common (Eastern) Garter Snake (*Thamnophis sirtalis pallidulus* and *T. s. sirtalis*) in this critical area is not particularly well resolved, but the scanty analysis by Jamie J. Haskins is laudably cautious. Specimens and photographs collected during the project are being prepared for submission to the Museum of Comparative Zoology at Harvard University, and a list of records with museum numbers will be available through Mac Hunter (page 165), but it is disquieting to read that curating had proved to be a major difficulty and that consequently many specimens were lost in the process. Many future workers will want to incorporate in their own work only those records which do have vouchers available for verification, as access to verifiable material is the only really credible basis for scientific acceptance of any records.

Maine now joins the Ontario and Quebec as units with successful atlassing projects. The latter provinces had earlier published interim reports and their surveys are still underway (see reviews in *The Canadian Field-Naturalist* 105(4): 612-614, 614-615). Considering the need for long-term monitoring for distributional change and fluctuation in abundance in all parts of North America, and the number of gaps still present for most species mapped in Maine, it is to be hoped that individuals will carry on the pursuit of additional data for all species beyond the narrow confines of this single finite project.

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Herpetology: An Introductory Biology of Amphibians and Reptiles

By George R. Zug. 1993. Academic Press, Inc., Harcourt Brace Javanovich, Publishers, New York. xv + 527 pp. Illus.

New research on amphibians and reptiles (long linked under the general term herpetology, but see below) increases at a rate inconceivable even a few decades ago. The reasons are varied. Partly the increase is a simple function of the vast numbers of scientists world-wide currently exploring every aspect of the natural world, the pinnacle of a spinoff from generous funding to universities particularly, and to a lesser extent museums, during a passing generation, coupled with an explosion of amateur interest, much of it enlightened. It is a small part of a frantic conservation imperative finally focusing beyond the highly showy and attractive birds and warm and furry mammals as the realization grows that the chance of saving significant ecosystems

while they are still relatively pristine is melting away before the onslaught of ever-accelerating human consumption. But also it reflects the full realization that broad questions of the workings of evolution, ecology, and behaviour can be simplified and analyzed through abundant and conveniently-studied individual populations and groups among the ectothermic tetrapods. This current health and vigour in herpetology supports three thriving major societies in North America alone (each with its own scientific periodical): The American Society of Ichthyologists and Herpetologists (*Copeia*, shared with fish research), The Herpetologists League (*Herpetologica*), and The Society for the Study of Amphibians and Reptiles (*The Journal of Herpetology*). *The Herpetological Review*, a mix of news and short research and observation notes, is also produced by the last named. In Great Britain, *The Herpetological Journal* and *The Bulletin of British Herpetological Society* serve similar niches, and variants of these occur in an increasing number of countries around the world in a range of languages. Smaller societies are also thriving with a narrower state, regional, or taxonomic group orientation and these and their publications are particularly abundant in the United States. Even Canada has its own society, the Canadian Association of Herpetologists, not yet a decade old, which issues its *CHA Bulletin* twice a year. Reviewed herpetological research appears in hundreds of other outlets such as topic journals — *Ecology, Behaviour, Systematic Biology, Genetics* ...; regional journals — *American Midland Naturalist, Canadian Journal of Zoology, Le Naturalist canadien, The Canadian Field-Naturalist* ..., institutional bulletins, monographs and other series. And even this listing barely touches the proliferation of new information as it omits the ever-expanding more informal literature, often focused on husbandry and conservation, the growth of atlases for states and provinces and the other regional reports on conservation issued in a variety of formats. A 1994 Herpetological Index includes more than 3000 references to papers published primarily in 1994 (available in book, DOS disk (text and endnote files), and Macintosh disk (text and endnote files) for US $15.00 for one, or $20.00 for two, from the Utah Association of Herpetologists, 195 West 200 North, Logan, Utah 84321-3905 USA) [*Marine Turtle Newsletter* Number 69, page 30, April 1995].

In the face of deluge of information, texts quickly become dated and new entry and review volumes are critically and continually needed. In North America, it is over 30 years since the undergraduate university-level *Introduction to herpetology* first appeared, and over 15 since it was last revised [C. J. Goin and O. B. Goin. 1962. W. H. Freeman and Company, San Francisco; Second edition 1971, Third edition (with G. R. Zug as third author) 1978], and over 20 since its competitor, *Herpetology* (K. P. Porter. 1972. W. B. Saunders Company, Philadelphia) was published. As well, in this period, different approaches to comprehensive summaries of reptiles and amphibians alone have been issued: the multi-volumed, multi-authored, *Biology of the Reptilia* (C. Gans and others, *Editors*. 1969 *et seq.* Academic Press; University of Chicago Press, 18 volumes) and the single-volume, dual-authored, *Biology of Amphibians* (W. E. Duellman and L. Trueb. 1982. McGraw-Hill Book Company, New York) as well as a variety of volumes on major taxa within each group (e.g., C. Ernst and R. Barbour. 1989. *Turtles of the World*. Smithsonian Institution Press, Washington), and the comprehensive 1986 *The Encyclopaedia of Reptiles and Amphibians* (Edited by Tim R. Halliday and Kraig Adler, Facts on File, New York, N.Y.).

George Zug, Curator at the Division of Amphibians and Reptiles, the United States National Museum, Smithsonian Institution, Washington, has had to face a double challenge: to incorporate as much new information as possible and to cope with the reality that traditional classifications are no longer systematically acceptable. The familiar four "classes": amphibians, reptiles, birds, and mammals are not equivalent groupings of vertebrates, and may give way to a cladistic approach producing relationships better reflecting their relative sequential history as we have come to understand it. The groupings that Zug outlines (page xiv) in his Preface are neither final consensus, nor even agreed on by all current workers, but serve to demonstrate the directions taken. Tetrapods are here divided into Amphibia and Amniota (all other tetrapods), the latter into Mammalia and Reptilia, and the latter into Testudines (turtles) and Sauria. Birds and crocodiles together form the Archosauria under the latter with Lepidosauria containing the Sphenodontida (the tuatara) and the Squamata (lizards, snakes, amphisbaenids). Having thus modernized his approach, and made the point that his subject matter no longer is two equivalent natural groups, Zug simply cautions the reader to understand "reptile" throughout as "non-avian reptile" and proceeds (though the text is far from thorough with the principles and application of cladism - these are further covered in the evolution and in the systematic sections which are "must" reading for anyone more than a decade removed from their last academic course in systematics).

The text is divided into six parts which together cover 18 chapters — Diversity and History (Amphibians, Origin and Evolution of Amphibians, Reptiles, Origin and Evolution of Reptiles); As Predators and Prey (Diet and Feeding, Defense and Escape); Life Cycle: Reproduction, Development, and Growth (Modes of Reproduction and

Development; Dynamics of Reproduction); Individuals and the Environment (Spacing, Movements, and Orientation; Homeostasis: Air, Heat, and Water); Populations and the Environment (Population Structure and Dynamics; Population and Species Interactions), and Classification and Systematics (Systematics: Theory and Practice; Caecilians and Salamanders; Frogs; Turtles and Crocodilians; Lizards, Amphisbaenians, and Tuataras; Snakes). These readable headings touch on all the traditional disciplines of embryology, physiology, biogeography, ecology, etc., etc. in a condensed and readable densely informative direct style.

A chapter-by-chapter bibliography covers 39 pages and includes nearly 900 individual references. The bulk of these are from the 1980s and 1990s, less than 7% are pre-1970. As the text itself gives no internal references for statements and conclusions, the chapter bibliographies are the indispensable lead into detailed discussions and documentation of the topics raised. Review articles which have their own comprehensive bibliographies been emphasized to reduce the number of entries included.

The book concludes with a 19-page index to scientific names which includes both text and illustrations, but there is no glossary of terms, no index to them nor to topics. Photographs of individual animals are too few for the diversity of the groups; diagrams and line drawings are generally informative and greatly enhance the text.

This will be a valued, and oft-consulted, addition to any naturalists or conservationists library for its up-to-date comprehensive overview of these ecologically important groups and their role in the contemporary environment; it is a must for anyone just starting into the field of herpetology in order to orientate themselves.

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The Bowhead Whale

By John Burns, Jerome Montague, and Cleveland Cowles. 1993. Society for Marine Mammalogy, Lawrence, Kansas. 787 pp., illus. U.S. $75.

This book combines the input of 38 authors and four editors and results in the reference text for Bowhead Whales. Each author is scientist working at a university, museum, consultant or governmental agency. The result is a detailed reference that amalgamates the information from over 700 papers on the Bowhead Whale. This creature, which can approach 50 tons, lives in the Arctic regions and like the Inuit must adapt to long summer days and the darkness of winter. It feeds its giant mass on tiny plankton, eating 100 tons a year. To successfully research this whale scientists must work in the stark surroundings and daunting conditions endured by the creatures they study. They must also work with a limited population of animals as the estimated remaining 8000 whales are only 14% of the pre-exploitation population.

The first chapter deals with international law and policy, from the earliest steps for protection in 1931. Most of the research has been undertaken since 1973, and in that time about $56 million U.S. has been spent. I was not impressed to find out the Canadian government's contribution was less than a quarter of a million. The second chapter provides an explanation of the complex environment of the Bowhead's annual range. Currents, ice conditions, and plankton levels are the major factors in Bowhead distribution, but many other variables must be considered. Chapter three is a detailed examination of the fossil history and classification of the Bowhead while the next four chapters deal with aspects of the whale's biology. Its anatomy, behaviour breeding, feeding, and reproduction are thoroughly documented. Distribution, population dynamics, growth, and population size are examined next. Finally, whaling and the other impacts of mankind are described and discussed.

This is a scientific book written by and for scientists. The reader must understand the technical terms and abbreviations as the authors assume you are familiar with them. This is not a simple problem, solved by looking up the words in a good dictionary, as you must have an understanding of medicine, physics, chemistry, meteorology as well as biology. For example, I am still trying to resolve the meaning of "Sv" when used to describe ocean currents. I use this abbreviation often to represent Sieverts — a measurement of radioactivity — which is clearly not the correct interpretation in this case. This is certainly the most difficult multi-disciplinary book I have read in a long while.

This does not mean that it is laborious in an unpleasant sense but that, while effort is needed, it is also rewarded. Also, many parts of the book are sufficiently descriptive that a wide range of people would have no difficulty with reading it. For example, there is a separate chapter on subsistence whaling that describes in detail how the aboriginal people went after Bowheads in flimsy-looking skin boats and with stone-tipped harpoons. The whole process seemed extremely risky to me but the author is content to call it a "dangerous undertaking". This chapter is full of unusual insights. Did you know that

some cultures tipped their harpoons with aconite poison and the mummified oil of whalers of renown? Similar informative and entertaining knowledge is contained throughout the book.

This detailed, scholarly book is a great contribution to whale literature and will be most valuable to the scientific and research community. It is an essential purchase for whale researchers and research organisations. It also has much information on conditions in the Arctic and will be a valuable resource for all scientists who work in this wild, cold region. Anyone, scientist or not, who has the opportunity to visit the far north and to look for Bowheads should, at least, seek out a copy and glean from it what they can.

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Kangaroos: The Marvelous Mob

By Terry Domico (Photographs by Terry Domico and Mark Newman). 1993. Facts on File, New York. xix + 202 pp., illus. U.S. $39.95; $49.95 in Canada.

We Canadians cannot relate to these animals and their habitat, but it is always fun to read about kangaroos in Australia. This book describes the biology of these animals and their interactions with people. Chapter 1 describes kangaroos, their evolution, present distribution, and physiology. Chapter 2 is devoted to reproduction and development of the young. This whole chapter is appropriate given that marsupials are essentially defined by reproductive characteristics. Chapter 3 deals with individual and mob (group) behaviour. Then follow three chapters giving specific details about particular species. We go from rat-size and mid-size kangaroos (with colorful species names such as potoroos, bettongs, quokkas, pademelons, wallabies) to species living on rock faces and in trees (kangaroos are a diverse lot) to the big kangaroos that we are used to seeing on TV. Then we come to an interesting chapter on commercial exploitation (did you know that Italian shoes may be made of kangaroo leather?), and finally a chapter on measures currently taken to better understand and conserve these animals (although a few species are so abundant they are considered pests, most are rare and threatened). The book closes with a list of further reading and two appendices, on raising orphaned young and on the conservation status of each kangaroo species. The writing style is pleasant and easy to read throughout. Within each chapter the text is divided into short, clearly marked subsections.

To be critical, I noted passages on physiology and behaviour that were too short. Three examples: only six lines, and no illustration, are devoted to the role of elastic tendons in making hopping a more economical mode of locomotion than walking (it certainly takes me more than that to explain this topic in class); kangaroos are said to pant when they are hot, but we are not told how panting helps to cool off; and the caption to a photograph tells us that eyeshine at night comes from the tapetum lucidum, a light-reflecting membrane at the bottom of eyes, but how does this membrane help animals see better at night? In contrast, there were some repetitions between the first three chapters on general biology and the following three chapters on particular species.

On the plus side, the text often comes alive with anecdotes experienced by the author while he did the research for this book in Australia, with reports of his contacts with several scientists working with kangaroos, and with interesting tidbits (for example, legend has it that "kangaroo" is what an Aborigine answered when asked by Captain Cook how the animal was named; there are now reasons to believe that "kangaroo" actually means "I don't understand"). I also liked the exposition of the paradoxical way in which Australians as a society treat kangaroos, at once adopting them as a national symbol, shooting them, trying to conserve them or to exploit them, or as one photograph shows, trying to play golf in the middle of a grazing mob of them. And speaking of photographs, they are abundant, all in color, and superb, as is usually the case with books from Facts on File.

Overall, I liked this book. This side of the Pacific, I am not aware of any better way to get acquainted with kangaroos.

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Lady Grayl: Owl With A Mission

By Robert W. Nero. 1994. Natural Heritage Natural History Inc., Toronto. 176 pp., illus. $19.95.

The mention of the name Robert Nero for many brings to mind the image of a research scientist dedicated to Great Gray Owls. The book *Lady Grayl: Owl With a Mission*, presents a different side of the man. This informal and very personal book describes his fascinating relationship and love affair with one specific member of the species.

Removed from a nest when it was apparent that she was going to perish next to her healthier and larger siblings, "Grayl", short-form for "Gray'l" or "Gray Owl" was subsequently reared in captivity. This book details Dr. Nero's fascination and close relationship with the owl from that early time. Imprinted upon humans, the owl could not be released into the wild, and thus became part of a very effective and popular human-owl natural history education team. After many years of travelling to schools throughout Manitoba and beyond, the author describes with obvious satisfaction and delight the owl's dramatic effect on school children. The owl was met with enthusiasm and interest wherever they went, with Grayl usually perched in the back of the author's station wagon. Many humourous anecdotes are related — of the reactions of passing motorists to an owl in the car, of shopping mall visitors assuming that the owl was a mounted specimen, of Grayl pouncing on a photographer's shoe. But the greatest impact was obviously on the children, who were enthralled with the size, majesty, closeness and sheer presence of the owl. Imagining an owl with such a long wingspan swooping over a group of schoolchildren in a darkened auditorium, it's easy to picture the impression this owl had on school children. As a precondition to school visits, school children learned about owl biology, and were involved in fund-raising for owl conservation. The resulting effect appeared to be overwhelming interest in and a greatly increased understanding of the owls, their biology and the need for their conservation.

Although the book is clearly not a scientific treatise, the author's observations of Grayl's behaviour often provide insights into the life and behaviour of wild owls, and help to interpret field observations. Grayl's uncanny ability to observe and fix on raptors at great distances, her ability to physically tune out unimportant noises and things in her daily surroundings, and her aggressive reaction to potential predators such as cats and dogs are a few examples. One entire chapter is devoted to a study of Grayl's moulting chronology, whereby Dr. Nero daily meticulously removed, identified, and enumerated feathers which Grayl moulted over the moulting period.

The book is interspersed with many black-and-white photographs depicting Grayl in a variety of situations. The pictures are interesting, and help the reader to identify more personally with the relationship between the owl and Dr. Nero, and to understand some of the described postures and behaviours. The snapshot nature of the photographs adds a photo album impression to the book's already personal nature.

It is the relationship between Dr. Nero and the owl that probably forms the central core of this book. Dr. Nero is obviously devoted to this creature, both as a representative of the species and as a personal companion in life. The author is very candid, perhaps almost too much so, in his affection for the owl. The author is not averse to ascribing emotion and personality to Lady Grayl. This facet, unusual in most natural history books, is perhaps best described in the written endorsement from Katherine McKeever on the back cover of the book: "it is heartening to find in Dr. Nero not just the able scientific mind but also a sense of wonder, undiminished by the years… His words remind us of joys we once knew, of worlds to which we have grown blind".

Another interesting aspect of this book is the inclusion of several poems written by the author, with the owl as the main subject. These poems shed light on the author's fascination with Grayl, and attempt to give an understanding of the world from the perspective of an owl.

Lady Grayl, Owl With A Mission will not appeal to all readers. It seems to lack a central coordinating theme, rambling from one chapter to another in no progressive sequence, and its focus on the author's personal relationship with this owl will be disconcerting to some. However, that same aspect will make this book special to others. There is none of the cold clinical observer here — the scientist's keen analytical eye is inseparable from the naturalist's love of nature, the child's fascination with the natural world, and the artist's love of poetry and form. This book is a unique blend of natural history, scientific observations, biography of an owl, poetry, family album, and a journal of discovery. It sheds as much light on Dr. Nero's inclusive approach to science as it does on Great Gray Owl biology. This book will challenge naturalists and scientists alike to look at the world they are studying in a much broader manner, with eyes wider open.

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Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians

Edited by W. Ronald Heyer, Maureen A. Donnelly, Roy W. McDiarmid, Lee-Ann C. Hayck, and Mercedes S. Foster. 1994. Smithsonian Institution Press, Washington, USA. xix + 364 pages, illus. Cloth U.S. $49; Paper U.S. $17.95.

This volume is the first in a Biodiversity Handbook Series established by the National Biological Survey of the United State Department of the Interior. The intended purpose of the series is to publish manuals "detailing standard field methods for qualitative and quantitative sampling... [to] focus on different groups of organisms, both plants and animals .... so that biodiversity information will be comparable across study sites, geographic areas and organisms, and at the same site, through time".

The material is divided among 10 chapters, 7 appendices, a glossary, literature cited, and index. The initial chapter is an introduction and touches on previous work ("no single [previous] reference describes techniques for the inventory and monitoring of amphibians and the circumstances where each is appropriate") and the intended audience ("to meet the needs of conservation organizations, environmental consultants, government agencies, wildlife managers, and scientists").

The other chapters cover virtually everything you might ask in initiating, carrying through, and analyzing the results of an survey: (2) Amphibian Diversity and Natural History: An Overview; (3) Essentials of Standardization and Quantification; (4) Research Design for Quantitative Amphibian Studies; (5) Keys to a Successful Project: Associated Data and Planning; (6) Standard Techniques for Inventory and Monitoring; (7) Supplemental Approaches to Studying Amphibian Biodiversity; (8) Estimating Population Size; (9) Analysis of Amphibian Biodiversity Data; (10) Conclusion and Recommendations. The appendices are (1) Handling Live Amphibians; (2) Techniques on Marking Amphibians; (3) Recording Frog Calls; (4) Preparing Amphibians as Scientific Specimens; (5) Collecting Tissue for Biochemical Analysis; (6) Vendors (equipment, supplies, computer programs); (7) Table of Random Numbers. The glossary covers 45 terms; everything from "species equitability" [=species evenness] to "U.S.$" for the complete neophyte. There are 22 pages of references to source papers and books.

Diagrams of data sheets and devices are provided throughout, and the written texts are simple to a fault, and straightforward enough for any audience. Much of what is developed in the pages will save both new and old inventory workers from re-inventing techniques and lead certainly to more comparable results from study to study. But the number of variations often belie the stated aim at standardization and perhaps this is unattainably utopian at present - no one good method or set of methods will likely standardize all areas, all species, all budgets (in terms of both time and funds), and all investigators, at all times. However, the book is a prime source for much of what has been tried and will serve as an inspiration for stimulation of future modifications and initiatives.

It has already become a virtual "bible" for the ever-expanding number of projects monitoring amphibians worldwide since global decline in amphibians was debated at the First World Herpetological Congress in England in 1989. The Decline in Amphibian Populations Task Force (DAPTF) of the IUCN (World Conservation Union) which grew out of this new world awareness soon had a strong Canadian component (DAPCAN), organized in Burlington (at Environment Canada), Ontario, in 1991, and subsequently meeting annually in Montreal (at Redpath Museum) in 1992, at Victoria (at the Royal British Columbia Museum) in 1993, at Winnipeg (at the Manitoba Museum of Man and Nature) in 1994, and at Burlington again, 29 September to 2 October 1995, and is presently nationally coordinated by Stan A. Orchard, Nearactic Zoophiles Inc., 1745 Bank Street, Victoria, British Columbia V8R 4V7, with regional and provincial coordinators across the country. Its own volume of Canadian studies is currently in advanced preparation, edited by David M. Green, Redpath Museum, McGill University, its past coordinator, to be copublished in the new conservation monograph series of the Society for the Study of Amphibians and Reptiles*. Monitoring projects are continuing in many provinces: two examples inviting local public participation are the "Backyard Frog" project (in Ontario, write Christine Bishop, Environment Canada, Centre for Inland Waters, P.O. Box 5050, 867 Lakeshore Road, Burlington, Ontario L7R 4A6) and "Frogwatch 95" program (in Nova Scotia, write Rhea Dawn Mahar, Nova Scotia Museum, 1747 Summer Street, Halifax, Nova Scotia B3H 3A6).

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**Amphibians in Decline: Reports from The Canadian Declining Populations Task Force.* Edited by David M. Green. *Herpetological Conservation.* A detailed account of concept, progress and final submission with complete table of contents is given by David M. Green in the *Canadian Association of Herpetologists Bulletin* 9(2): 5–7; Fall 1995. Membership in the Canadian Society of Herpetologists in $10 annually. Dr. P. T. Gregory, Treasurer CAH/ACH, Department of Biology, University of Victoria, Victoria, British Columbia V8W ZYZ

Quaternary Insects and their Environments

By Scott A. Elias. 1994. Smithsonian Institution Press, Washington. 284 pp., illus. U.S. $40.

Quaternary palaeoecology and environmental reconstruction have always relied heavily on pollen analysis, to the extent that evidence from other proxy environmental indicators has, until recently, been virtually ignored. It is really only in the last few years that a rapprochement has begun between those investigating plants and those using other proxy indicators, whether limnological, such as diatoms, or terrestrial, such as insects. To most of us who work with plant material, the insect world remains mysterious, and baffling in its complexity. In this clear and comprehensive book, Scott Elias goes to great lengths to dispel some of this mystique.

The first five chapters of the book deal with the history and development of Quaternary insect studies, including modern methods of numerical analysis that are successfully deriving numerical climate estimates from insect assemblages. Elias' discussion of insect biology emphasizes two major aspects: the stability of taxa over long intervals of geologic time, and the mobility and rapid dispersal capabilities of many forms. Rather than being extinguished by the climatic events of the Quaternary, insects have migrated to more agreeable areas. As Coope comments in his foreword, insects have "responded to these climatic changes by *moving* out of trouble rather than *evolving* out of trouble".

The sheer number of insect taxa is awesome. Elias cites estimates that there are 300 000 known species of beetles alone, with about 1500 new taxa being added each year, adding that "beetles account for 25% of all known species of organisms, a quantity that is more than all flowering plants combined" (page 55). Given these figures, it is predictable that Quaternary insect studies consist, for the most part, of the analysis of fragmentary bettle remains.

With such a large fauna, it is not surprising that identification and taxonomic problems bedevil the subject. Elias describes several studies (pages 3-9) in which extinct species were identified or named but subsequent re-examination of these specimens, in the light of better reference collections and methods (e.g., SEM), has shown them to be identical to extant taxa. This emphasizes the importance of proper specimen curation so that materials can be available to future researchers. I suspect that similar taxonomic problems may become more acute when studies are extended to areas of the world in which insect faunas are poorly-known or where isolated researchers, without recourse to extensive reference collections, have named local species that may turn out to be identical to known taxa elsewhere. Elias hints at this problem himself later (page 173) in his discussion of Siberian work. Although Elias does not mention it, this seems to me one area in which modern methods of electronic data (including image) transfer and on-line databases from some of the larger comparative collections could be extremely useful.

The next two chapters deal with some major topics, comprising insect zoogeography and insect studies in archaeology. I found the discussion of archaeo-entomology especially interesting. The picture of squalor presented by these studies is appalling and conveys a rather unattractive vision of the past. In the UK and Europe, archaeo-entomology has concentrated on the insect remains associated with dwellings and human remains, whereas in North America, with fewer habitation sites, palaeoentomologists have concentrated on human remains (especially mummified corpses) and coprolites (fossil faeces) (page 125). For sheer filth, the image of ancient York is hard to beat: flea-bitten lice-infested people living in houses carpeted with insect-ridden straw or rushes where meat and food-scraps rot. Although one hopes that the density of personal fauna is less in modern society, some of the domestic pests identified from the European archaeological record (e.g., death-watch bettles) are still significant problems.

In the following four chapters, Elias goes on to review insect studies in some major world regions (Europe, Siberia, Eastern Beringia, and the New World). Given the size of the regions discussed, the number of fossil insect studies is quite small. Not surprisingly, given the influence of Russell Coope and his students, the UK and Western Europe have the greater density of studies. Of the 119 studies listed for North America (excluding Eastern Beringia), 36 are from Canada. Alberta and Saskatchewa, however, stand out as conspicuous blanks on the map. These chapters are extremely useful, drawing together and synthesizing literature from disparate and diverse sources. One point that struck me forcefully is not the lack of suitable sites for insect studies, after all most of the peatland or wetland sites investigated by palynologists are likely to yield insect remains, but the dearth of qualified researchers to do the work. Elias lists only 37 researchers from nine countries who are studying Quaternary or Tertiary insect remains (page 12). The labour-intensive and time-consuming identification phase of the projects must limit the number of sites that any one researcher can handle. Even recognizing this limitation, the productivity of a few researchers is impressive; the same few names recur throughout these chapters.

The final chapter outlines the prospects for Quaternary insect studies. Elias points out that, for this "fledgling field in science" (page 223), the era of collaborative work is only just beginning. As for future initiatives, Elias comments on the potential of isotopic analysis of fossil insect cuticle material and DNA analysis of (rare) preserved soft tissues.

The book is completed by an appendix listing scientific and common names for the insect and arthropod taxa mentioned in the text, an extensive reference list, a glossary of terms, and an index. The book is generally well-produced with very few typos. There are plenty of illustrations, including line-drawings, distribution maps, site photos, and SEM images of insects. I found some of the landscape photos a bit dark (e.g., Figure 1.2, Figure 9.4). The labels on the insect distribution maps in Chapter 6 are too small to read comfortably; it would have been helpful to have these included in the figure captions.

This book is sufficiently well-written and illustrated that I think it will appeal to a general reader curious about the techniques available to investigate Quaternary environments. It would be eminently suitable as reading for a senior undergraduate or graduate course in Quaternary methods. At $40 (U.S.) the book represents good value for money. Specialists in other branches of Quaternary studies, especially palynology and archaeology, should also find much of interest here. I feel sure that Elias' articulate championship of his discipline will result in more collaborative work, which can only benefit Quaternary studies as a whole.

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Turtles of the United States and Canada

By Carl H. Ernst, Jeffrey E. Lovich, and Roger W. Barbour. 1994. Smithsonian Institution Press, Washington. xxxviii + 578 pp., illus. $U.S. 60.

This large book is an updating of Ernst and Barbour's 1972 publication, *Turtles of the United States*. A new edition was long overdue as major advances have been made in turtle ecology over the last two decades. For example, at the time of the previous book it had not yet been discovered that the sex in individuals in many species depends upon the incubation temperature of the eggs.

The authors provide detailed life history information for 56 species of freshwater and marine turtles. Species accounts range from 5-20 pages in length and are organized under a variety of subheadings, along with a distribution map. All the information is thoroughly referenced and the bibliography is over 90 pages long. The book also includes over 200 black-and-white photos illustrating details such as diagnostic features and subspecies variation, and a large colour photo of each species.

From a Canadian point of view the book does have its flaws. The distribution maps are somewhat misleading. For example, the book shows the painted turtle distributed across all of extreme southern Alberta — including the mountains — when really it is only found in southeastern Alberta (Cook 1984). Similarly, the book shows the spotted turtle to be absent from all of eastern Ontario when really it is present there (Cook 1984). In addition, the conservation section deals only with US legislation; there is not even any mention of COSEWIC. A reader would never realize, for example, that the Eastern Spiny Softshell Turtle has been designated threatened in Canada. Nonetheless, despite the United States bias, this is a valuable, although expensive, reference book on the turtles of North America.

Literature Cited

Cook, F. R. 1984. Introduction to Canadian Amphibians and Reptiles. National Museum of Canada, Ottawa. 200 pages.

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Editors note: Additional records for Alberta are plotted by A. P. Russell and A. M. Bauer. 1993. *The amphibians and reptiles of Alberta,* University of Calgary and University of Alberta Presses, but only the southeastern records are believed to be natural occurrences for Alberta.

Behavioral Mechanisms in Evolutionary Ecology

Edited by Leslie A. Real. 1994. University of Chicago Press, Chicago. ix + 469 pp. U.S. $80; paper U.S. $32.95.

Over the past decade there has grown the realization that disciplines such as ecology, ethology, physiology, and psychology that have traditionally operated mostly in isolation, have much to gain by sharing approaches and observations. Major topics include how and why animals perceive their worlds as they do, what and how they learn, and genetic and experiential aspects of feeding, mating, and communication. This book is one result of the realization, particularly, that questions regarding function in animal ecology cannot be fully answered without complementary attention to those regarding mechanism.

The volume is based on a 1992 symposium of the American Society of Naturalists and an expansion of an ensuing supplement of *American Naturalist.* The editor introduces the overall topic, levels of analysis, and subsequent organization of the chapters. Under

psychologicial and cognitive foundations, Kamil effectively argues for a more adaptive and synthetic approach to animal intelligence, Krebs and Inman provide a succinct account of ecological approaches to learning in foraging, and Dyer and Real each present an impressive suite of models for behaviour by insects. Importantly, these chapters do not become mired in the many sterile controversies that plague this area.

Under communication, Ryan's review of sexual selection includes modelling with neural networks that produce surprising results. Under neural, developmental, and genetic processes, intriguing findings include the role of the cerebral synthesis of plasma estrogens in the song development of zebra finches (Arnold), how vocal communication in cowbirds is far from the closed system that has been asserted (West et al.), evidence for diet expansion in phytophagous insects (Singer), and key linkages among behaviour, life cycles, and ecological relations in foraging sunfish (Werner). Under hormonal processes, Ketterson and Nolan superbly demonstrate for juncos the impact of testosterone on both behaviour and life history while Zuk effectively introduces psychoneuroimmunology as a field of great promise. Under the social context of behaviour, there are excellent and critical examinations of the controversial area of social cognition in primates (Seyfarth and Cheney) and of insect colonies in variable environments (Gordon).

Other chapters have various weaknesses such as technical overdosing, unclear impact, or no empirical data, new ideas, or general applicability. Referencing and indexing are good, and illustrations are for the most part well used. There is much varied and detailed information in this book, ranging from specific experimental results to considered reviews of broad topics. While some of the material is more valuable than other, there are many genuinely exciting methodologies and outcomes, and the ensemble is a rich resource.

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The Timber Wolf in Wisconsin: The Death and Life of a Majestic Predator

By R.P. Thiel. 1994. University of Wisconsin Press, Madison. xxiv + 253 pp., illus. Cloth U.S. $45; paper U.S. $17.95.

Few animals in North America have triggered as much debate and praise as the wolf. From centuries of persecution to eventual complete protection, the wolf has managed to survive in only a fragment of its historic range in the contiguous United States. The perceived and real competition between wolves and people for resources, along with the fear wolves undoubtedly invoked, was to secure this species' fate in many areas of North America and elsewhere.

Wildlife biologist and former chair of Wisconsin's wolf recovery plan team, Richard Thiel has amassed and summarized an exhaustive collection of historic documents that illustrate the relationships between wolves and humans in Wisconsin. Thiel's objective for writing *The Timber Wolf in Wisconsin* was to provide a critical historical account of the wolf and describe human attitudes and actions that led to its extirpation. I believe the author has met this objective admirably.

This book is divided into nine chapters, which include a basic discussion of wolf ecology, the colonization of Wisconsin by humans, interactions between wolves and humans, stories of trappers' experiences with wolves, the government bounty system in Wisconsin and Michigan, wolf management in Wisconsin in relation to deer populations and prevailing politics, an in-depth look at an unpublished multi-year study of wolves in Wisconsin, the extirpation of the wolf in Wisconsin and Michigan, and a discussion of the future for wolves state-wide and regionally.

The chapters are followed by five appendices. The first describes specimens of wolves from Wisconsin that are catalogued in several regional museums and private collections, which amazingly comprise less than 20 individuals. Appendix 2 provides a brief discussion of wolves in relation to dogs and coyotes and the potential for interbreeding. Appendix 3 provides short biographies of six biologists that studied wolves in Wisconsin, most notably Aldo Leopold. Historical accounts of "subpopulations" of wolves in Wisconsin and the upper peninsula of Michigan, including the number of animals observed in each pack and the approximate latest year their presence or definitive sign was observed are described in Appendix 4. The last appendix provides state-wide population estimates, bounty claims, and calculations used to explain numerically the extirpation of wolves in Wisconsin.

Throughout the book are figures and tables which are readily understood and complement the text well. Photographs used were well selected and provide improved comprehension of the time period described. I noted only a few typographical errors in the entire manuscript.

Though not the author's fault, because of the nature of material presented, the reading is some-

what dry. Several of the stories appear in different forms among chapters; however, Thiel's treatment of information was well defined overall and presented in a logical fashion.

Numerous books have been written about the wolf, the majority being scientific monographs or children's stories. *The Timber Wolf in Wisconsin* is unique in that it provides an accurate (as possible) historical account of this species and how it is completely intertwined with human sociology. Though this book was written specifically about wolves in Wisconsin, the human attitudes and perceptions portrayed were likely cosmopolitan in scope.

Overall, I believe the author has provided an excellent historical account of our most popular, yet misunderstood predator. This book will be of considerable value to anyone interested in the history of wolves in Wisconsin.

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Biology of North American Tortoises

Edited by R. Bruce Bury and David J. Germano. 1994. Fish and Wildlife Research Number 13: 1–204, illus. Free. Publications Unit, United States Fish and Wildlife Service, 1849 C St. N.W., Mail Stop 130, Webb Building, Washington, D.C. 20240.

The four allopatric species of *Gopherus*, the only extant genus of North America tortoises, inhabit deserts and scrubland in parts of the southern United States and northern Mexico. Urbanization and agriculturalization across parts of the natural range of these tortoises, particularly in northern Florida and the American southwest, has led to concerns over their continued survival. *Gopherus* has consequently been the focus of numerous studies, to the extent that it is arguably one of the best known genera of North American reptiles. The 17 papers, contributed by 18 authors, in the *Biology of North American Tortoises*, are the latest addition to the voluminous body of literature on *Gopherus*.

In their introductory chapter (pages 1–5), the co-editors emphasize that a comprehensive understanding of the biology of extant *Gopherus* has yet to be achieved, despite intensive study of these tortoises over the past few decades. This situation has significant repercussions, because management and conservation policies are guided by information derived from field studies of natural populations. However well-intended these protective measures may be, they are, in the final analysis, only as effective as the data upon which they are based.

Charles Crumly's (pages 7–32) cladistic analysis of inferred relationships among extant and fossil North American tortoises is arguably this volume's most significant contribution, because it provides a systematic framework for investigating and interpreting the biology of North American tortoises (see discussion of this methodology by Brooks and McLennan 1991). Unfortunately, the basic biology of each extant species of *Gopherus* must be better documented before such phylogenetically-based comparative studies can be undertaken. Aside from a short taxonomic paper, the remaining thirteen research papers are devoted to ecological topics, specifically: habitat use and demography (five papers), feeding (two papers), and reproduction and life history (six papers). Eleven of these contributions focus on a single species, within either part or all of its geographic range: *Gopherus agassizii*, six papers; *A. flavomarginatus*, one paper; *A. polyphemus*, four papers. No paper is devoted exclusively to *G. berlandieri*. More comprehensive papers are by David Morafka (pages 161–173), on the biology of *Gopherus* hatchlings, and by David Germano (175–185), on comparative life histories among extant species of *Gopherus*.

The co-editors' summary paper (pages 187–204) includes a critique of past research on North American tortoises and recommendations for their future study. Persons interested in making worthwhile contributions to the study of these tortoises in particular, and turtles in general, will find this chapter filled with potential research projects. I found this final chapter particularly enlightening, because it explicitly and honestly identified strengths and, more importantly to my mind, weaknesses in our current knowledge of North American tortoises. Biologists striving for a comprehensive understanding of other taxonomic groups would benefit from undertaking similar, critical self-examinations of their data.

This volume is not an exhaustive account of North American tortoises, unlike, for example, the *Life History and Ecology of the Slider Turtle* (Gibbons 1990). Nevertheless, the *Biology of North American Tortoises* is an informative work that is well worth acquiring.

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Brooks, D. R., and D. A. McLennan. 1991. Phylogeny, Ecology, and Behavior. University of Chicago Press, Chicago. 434 pages.

Gibbons, J. W., *Editor*. 1990. Life History and Ecology of the Slider Turtle. Smithsonian Institution Press, Washington. 368 pages.

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Atlas des Amphibiens et des Reptiles du Québec

By J. Roger Bider and Sylvie Matte. 1994. Société d'Histoire Naturelle de la vallée du Saint-Laurent et Ministère de l'Environnement et de la Faune du Québec, Direction de la faune et des habitats, Québec. 106 pp. illus. $12.00 (including handling and postage, available from St. Lawrence Valley Natural History Society, 21125 chemin Ste-Marie, Ste-Anne-de-Bellevue, Quebec, Canada H9X 3L2).

This edition of the Quebec atlas project for amphibians and reptiles follows two earlier ones: a "Version préliminaire" in 1990 and a "Version détaillée" in 1992 by the same authors (see *The Canadian Field-Naturalist* 105(4): 614–615). Whereas the earlier reports were solely maps with detailed documentation for each known record, the present edition contains species accounts, illustrations, and updated maps without repeating the detailed record documentation in earlier editions.

The project began in 1988 and continues into the present, but the records contained on the maps in this edition only bring the data base up to include 1992. Still, there are three new species added to bring the Quebec native total to 37. One, the Boreal Chorus Frog, *Pseudacris maculata*, is the result of accepting the elevation of this form to species status (following J. E. Platz. 1989. Speciation within the chorus frog: morphometric and mating call analyses of the boreal and western subspecies. *Copeia* 1989(3): 704–712), rather than continuing to regard it as a subspecies of *P. triseriata*. The other two are the addition of the Mountain Dusky Salamander, *Desmognathus orchrophaeus* (T. F. Sharbel and J. Bonin. 1992. Northernmost record of *Desmognathus orchrophaeus*: biochemical identification in the Chateauguay River Drainage Basin, Quebec. *Journal of Herpetology* 26(4): 505–510), and the Musk Turtle (J. Chabot and D. St-Hilaire. 1989. Première mention de la tortue musquèe, *Sternotherus odoratus* au Quebec. *The Canadian Field-Naturalist* 105: 411–412). Two certainly introduced turtles, the Slider, *Trachemys scripta*, and the Box Turtle, *Terrapene carolina*, have been dropped.

The present format gives two pages per species, slightly over a page of text plus an illustration and a map, the latter usually three-quarters of a page. There are no subheadings but roughly covered are general remarks, description, distribution, and biology. Only the most interesting records are mentioned and they lack details. The illustrations, by Rosemarie Schwab are generally excellent; her snakes have scales (not just the hazy hatching of some less conscientious illustrators), her turtles are generally superb, her frogs good (except for some peculiar crinkled mouth lines; i.e., the Bullfrog page 48), as are her salamanders (except for some rather awkwardly tilted heads, especially in the Four-toed Salamander page 28). The maps are clean and sharp, a major improvement over earlier editions. Regrettably, a grid system has been used instead of dots of precise localities. Although it would doubtless be politically unacceptable to both Quebec and Newfoundland, it would have been more biogeographically instructive to have included Labrador records in the mapping - documentation of known records already exist (J. E. Maunder. 1983. Amphibians of the province of Newfoundland. *The Canadian Field-Naturalist* 97(1): 33–46). These would have put certain northern Quebec records in proper context and been better than the solution here, to include Labrador on the base map but leave it blank. The maps still emphasize the time period each record was made, distinguishing pre-1988, 1988-1992, and ones from both periods. It also would have been instructive to have depicted those records documented by specimens or photographs and those based solely on unverifiable observations by sight or ear. Apparently a record based on misidentified tadpoles from the Canadian Museum of Nature from the central portion of the province, mentioned in a previous review, has been retained for the map of the Boreal Chorus Frog due to the inadvertent mapping omission of a question mark the authors had in their data base. Other records that need particular verification include the Bullfrog from south of Lake Mistassini, Wood and Snapping turtles from the Gaspè, the Brown Snake and Milk Snake from the lower St. Lawrence River. The list of references is not a bibliography for Quebec herpetology but only a portion of it.

These, however, are minor points. This is a fine progress report, enhanced by a good base map, attractive illustrations, and interesting text.

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The Reptiles and Amphibians of the Hamilton Area: A Historical Summary and the Results of The Hamilton Herpetological Atlas

By William G. Lamond. 1994. Hamilton Field-Naturalists' Club, Hamilton, Ontario. 174 pages, illus. $20.90 (available from the Hamilton Naturalists' Club, P. O. Box 89052, Hamilton, Ontario L85 4R5; price includes postage and handling).

Ever faster, time is running out on the last opportunities to conserve some vestiges of the natural world. Increased awareness is manifest in the spreading focus on the totality of life or "biodiversity" (for example, the Canadian Museum of Nature's serial, *Canadian Biodiversity*, subsequently re-christened *Global Biodiversity*). As consumptive human demand for resources and space reaches into all corners of the environment, ever-increasingly precise data is demanded on occurrence, relative abundance, and relationships of individuals and ecosystems to plead for their continued existence. Even those relatively most neglected vertebrate groups, amphibians and reptiles, have justly received a share of this attention: provincial field guides detailing their distribution (the latest for Alberta - see review in *The Canadian Field-Naturalist* 108(3): 379–380), Status reports of individual species (Committee on the Status of Endangered Wildlife in Canada, COSEWIC, have been produced and released in manuscript, some formally published - see *The Canadian Field-Naturalist* 103(4): 486–496, 109(2): 182–191) and provincial atlases, led in Canada by Quebec and Ontario (see reviews in *The Canadian Field-Naturalist* 105(4): 612–615; 109(4): 493); special attention on overall amphibian declines (C. A. Bishop and K. E. Pettit. *Editors*. 1992. Declines in Canadian Amphibian Populations: Designing a National Monitoring Strategy. Canadian Wildlife Service, Occasional Paper Number 76. 120 pages) and even a full symposium on a single species (B. Johnson and V. Menzies. *Editors*. 1993. International Symposium and Workshop on the Conservation of the Eastern Massasauga, *Sistrurus catenatus catenatus*. *Edited by* Bob Johnson and Vi Menzies. Metropolitan Toronto Zoo, Toronto, Ontario. 132 pages).

However important the broad context, ultimately conservation is a local issue; site-by-site decisions taken incrementally decide the fate of each species. Of first importance is knowing where populations of species exist. Presentation of this detail is therefore especially valuable: in Ontario preliminary data on distributions in the vicinity of two urban centres have been mapped (F. R. Cook. 1981. Amphibians and Reptiles of the Ottawa District. *Trail & Landscape* 15(2): 75–109; B. Johnson. 1982. Amphibians and Reptiles of Metro Toronto. Toronto Field-Naturalists Club, Toronto, Ontario) and a detailed systematic survey pioneered for one other (G. R. Francis and C. A. Campbell. 1983. The herpetofauna of the Waterloo Region, Ontario. *Ontario Field Biologist* 37(2): 51–86), the latter forming the inspiration for the current atlas, a tribute to the tremendous imputus to conservation of amphibians and reptiles given by the extensive work and reports of Craig Campbell in southern Ontario thoughout the 1960s to 1980s.

This atlas adds another important Ontario urban centre, Hamilton, covering the area enclosed within a 40.2 km radius centred at Dundurn Castle, and thus taking in portions of the political counties or regional municipalities of Brant, Haldimand-Norfolk, Halton, Hamilton-Wentworth, Niagara, Peel, Waterloo, and Wellington, from the southern portion of Mississauga in the northeast to Brantford in the southwest. Detailed species accounts are presented for 31 species which are still thought to exist in the area, 5 additional species are given as of former occurrence, 7 of doubtful occurrence, and 3 as introduced, for a total of 47 (a significant portion of the 89 totals, including introductions, recorded for all of Canada. For the first category, the accounts are detailed and give Life History, Ontario Distribution, Hamilton Area Pre-1960, Hamilton area 1960-1983, Hamilton Herpetofaunal Atlas 1984-1992. The first gives a thorough and up-to-date survey of the existing literature, the others discuss the records of each period in detail with references and personal communications. Each species is illustrated with a photograph (all by Kathleen Gardiner, except for one each by Christine Bishop and Don Sutherland) and many additionally decorated by sketches (by Premek Hamr, Marlene Ross, Denys Gardiner, and Chris Gardiner). The core of the book is its maps (developed by Brain Klinkenberg with data entry by Kathleen Gardiner). These are based on a system of 2 km squares. Although not as informative as plotting the records precisely, this method has great appeal for a cooperative survey as it challenges observers to fill in squares for each species and thus psychologically gives impetus to searching ever more thoroughly for rarer forms. The number, 1142 squares, assures a fairly good resolution. The successes of the venture speaks for the method; the Hamilton Herpetological Atlas study team of students employed in 1988-1990 accounted for 6907 records, volunteers from the Hamilton Field-Naturalists' Club during 1987-1992 for 2504, those from the province-wide Ontario Herpetological Survey, 1984-1992 (see above) 2453, and landowners through contact with the study team contributed 2956 records.

Prefixing accounts of species are sections containing Acknowledgements, an Introduction, a Literature Summary for the area, Methods, a List of Volunteers, Conservation Perspective, Format and

Explanation of Species Accounts, Cited Observers and List of Symbols and Abbreviations. Valuable inclusions are four base maps of the study area which show roads, remaining forest cover, species diversity, and political divisions. A strong point of the treatment is the lengthy discussion of the Blue Spotted-Jefferson Salamander Complex (*Amystoma laterale*, *A. jeffersonianum* and their hybrids) first in the introductory section and again in the species accounts. These have been written in close consultation with J. P. Bogart, University of Guelph, who cooperated with the project by analyzing specimens in his laboratory, and underscore the vital importance of voucher collections and locality-by-locality examination of variation. The detailed discussions included in each account of rarer species of records and possible status is also of special value. A six-page bibliography concludes the atlas.

This publication, a model of thoroughness and quality, is not just an essential stepping-stone for conservation in the Hamilton area, which arguably is now the best-documented area in Canada for amphibians and reptiles, but also should serve as an inspiration to naturalists' groups throughout the country who consider initiating local surveys. Also it is a valuable reference for any naturalist in eastern Canada for its discussion of literature and observations of natural history for species common to this wider region.

It is to be hoped that the Hamilton Field-Naturalists' Club will use this milestone as a base and continue to monitor these groups, document further changes, and fight for the local preservation of amphibian and reptile habitat based on its data. All those who contributed should feel justly proud of this beginning, not the least Don McLean who designed the publication and carried out typesetting and layout which have contributed materially to its ease of use.

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The Northern Goshawk: Ecology and Management

By W. M. Block, M. L. Morrison, and M. Hildegard Reiser. Editors. 1994. Studies in Avian Biology Number 16, Cooper Ornithological Society. Available from W. Wehtje, Western Foundation of Vertebrate Zoology, 439 Calle San Pablo, Sacramento, California 93010. vi + 136 pp., illus + plates. U.S. $16.00.

This is a collection of 22 scientific articles, from a total of 41 contributors, forming the proceedings of a symposium held by the Cooper Ornithological Society in Sacramento, California, on 14–15 April 1993. Of the 22 articles, 18 are based on research done in the Southwestern United States, 2 more are from Oregon, 1 is from the Yukon, and the last one comes from the New York-New Jersey Highlands. The heavy western bias stems from the fact that the Northern Goshawk has been declared a Forest Service Sensitive Species within the Rocky Mountain and Intermountain regions. As an indicator species for mature forests, the goshawk bears resemblance to the well-known Northern Spotted Owl, a western species on which a similar symposium was organized in 1984.

The first six papers are grouped under the section "Research Approaches and Management Concepts"; two provide conceptual frameworks, one examines the relationship between stand density and vegetative structural stages, and three describe techniques (on estimating the age of nestling goshawks, on locating their nest by measuring the response of parents to taped broadcast calls of conspecifics, and on assessing habitat with a stand density index). The next section, entitled "Resource Ecology", contains five papers on habitat selection and use, two more on territory characteristics, another one on the correlation between body size and nest habitat characteristics, and one on the diet of goshawks in Ponderosa pine forests. The last section, "Population Ecology", features three papers on nest productivity, two articles on survival rates and mate retention, another one on the population response of goshawks to changes in the number of snowshoe hares (the Yukon study), and one more on the results of a food supplementation study.

This collection of papers is meant to represent the current state of knowledge on Northern Goshawk ecology, apparently with a view to influence forest management practices. Possibly because the work is diversified and, in many cases, still in progress, no general take-home message seems to have emerged from the symposium, at least not in written form (there is a short introduction to the book, but no concluding remarks). Nevertheless, this book should be of interest to professionals working on the ecology of forest-dwelling birds, or on the general biology of forest-dwelling raptors.

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Handbook of the Birds of the World, Volume 2: New World Vultures to Guineafowl

By Josep del Hoyo, Andrew Elliot and Jordi Sargatal. Editors. 1994. Lynx Edicions, Barcelona, Spain. 638 pp., illus.

There are some enthusiastic birders who think the large, compendium-style books only give superficial coverage and are not worth buying. They say these glossy and expensive books are more suited to adorning a coffee table than providing useful information. I disagree with this viewpoint for two reasons. First, any well-written book is worth owning. All of us have and use more than one bird field guide because there are differences in style and content that are useful. The encyclopedia style represent another approach. The second reason is I like to make direct comparisons between birds I know well - Red-tailed Hawk - and those I have never seen - Hawaiian Hawk - before I visit a new location. This helps me establish a perspective for the new bird. It is easier to make this comparison when the artwork and text style are consistent as in this type of book.

Birds of the World volume 2 is a large, glossy and expensive book. The cost of this single volume is only a part of the consideration. It does not make sense to purchase only one of the volumes and this implies a commitment to buy the anticipated 12-volume set; a substantial capital outlay. Is it worth it?

This is the second book of an ambitious project to document all the world's species of birds in a single set of volumes. It covers all the birds of prey and their allies and the grouse, pheasants, and their kin. The book is divided up by family, resulting in twelve sections. Each section begins with an introduction to the family traits. Taking the New World Vulture family as an example, the introduction begins with a review of the systematics, where a convincing case is made to group these birds with the storks rather than the birds of prey, as is more traditional. The taxonomic problems of Greater and Lesser Yellow-headed Vultures and the potential for a split of Turkey Vulture into three species is explained. It is likely we will have to rely on DNA studies to resolve issues like these. The introduction also includes habitat and habits, food and feeding, movements and breeding, and status and conservation. As this introduction is fairly comprehensive, the individual species accounts are relatively short, being a summary of the components listed for the introduction as they apply to each species. Also included is a small, but clear, range map.

The introductory sections are illustrated by some of the finest photographs I have seen, including some remarkably good flight photographs. The individual species accounts have field-guide style plates created by ten artists. These people have managed to submerge their individual temperaments to achieve a reasonably consistent style. There are some differences. Some of the illustrations of the partridge and francolins are of a little poorer quality than the hawks. This is not the case for the grouse. Indeed, I was able to watch about 20 Sharp-tailed Grouse dance their way into a prairie morning the day before I wrote this review. My direct comparison between the text and illustrations and the live birds fared well. My guide at the dance did, however, provide me with considerably more detail on Sharp-tail behaviour than is given in the book but then he has been studying these grouse for thirty years.

In the sections where I know I am current with the very latest knowledge, such as the breeding biology of the Osprey, this book is almost up to date. This is not surprising, as there must have been some delay between the final manuscript and distribution of the finished product. As far as I can judge, the information is accurate and valid to the date of publication. The description and anecdotes are presented in an interesting and informative manner. The more I read this book the more I enjoyed reading it. There is a wealth of information to satisfy the ardent birder's quest for knowledge as well as providing some pleasant, but informative relaxation.

For those who have the money, this is a worthwhile purchase. It will be a source of information and enjoyable entertainment in the bleak days of winter. The American Birding Association's recent poll of its members showed the typical birder to be 53 years old with an income of $72 000 Can. This group are typically round-the-world birders who are likely to buy such a book. For those with less money I suggest you encourage the local library to add it to their shelves.

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Legendary Northwoods Animals

By G. Winter. 1994. Willow Creek Press, Minocqua, Wisconsin. xi + 126 pp., illus.

In the constant struggle to keep abreast of current knowledge, the latest discoveries, and day-to-day living, many people find themselves with less and less time to enjoy a more leisurely pace. For those requiring a short vacation from their stress-induced lifestyle, *Legendary Northwoods Animals* may be just the ticket.

Galen Winter has compiled a selection of tales of previously "undocumented" wildlife species that have been topics of discussion around logging and hunting camps and finer establishments for years. His satirical interjections of humor prevent this book from becoming yet another fictitious field guide. Winter possesses an uncanny ability to tactfully criticize without becoming a nuisance.

The book is divided into two parts. Part one contains accounts of 25 "Authenticated Legendary Animals" including the Freddycat, Hoop Snake, and Upland Trout. Each account consists of a two-page written description, a black-and-white illustration, and map delineating the species' current and historic ranges. Part two consists of brief one or two page accounts of six "Unauthenticated Mythical Animals".

It was reassuring to see some northwoods tales put down in writing. Having been born and raised in northern Wisconsin, I found several of these creatures particularly amusing and easy to relate to, especially the Great Northern Snow Snake and Whitetail Deer. The versions I have heard differed somewhat from those written here; however, the number of variations is likely equal to the number of individuals who have told the stories.

Winter has done a fine job of procuring laughter from this reader. His book will appeal to, and be appreciated by a broad spectrum of individuals in the upper Great Lakes region. Those lacking a sense of humor would best look elsewhere.

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Where to Watch Birds in South America

By Nigel Wheatley. 1994. Princeton University Press, Princeton. 431 pp., illus. U.S. $35.

A couple of years ago I was in Rio de Janeiro for a few days and wanted to do a bit of birding. I poked around a few book shops and looked in on the gift shop at the Botanical Gardens, but was unable to find useful information on where to go, or even a decent field guide (in any language). With the publication of this volume, no traveller need ever suffer that fate again.

Birding volumes of the "where to" variety are enormously variable, and mostly of very limited use. Wheatley's effort will stand with a select handful of such publications that not only provide useful information on where to go to see birds, but present brief sketches of the habitat and other ecological features of interest to any traveller with an interest in natural history, gives a little information on accommodation and transportation, and presents a reasonable list of species to be expected at each site.

Lists for each site are not comprehensive, but are organised under the headings *Endemics, Specialties*, and *Others* that provide the key information most serious birders would need to choose a destination. Information on climate, health and safety, geography, habitats, conservation, and bird families are provided for each country, along with a summary of how many species might reasonably be expected by a fanatical birder from a typical vacation within each nation's borders.

One feature that will prove useful to first time birders in South America, is a short list of recommended books. Although roughly a third of the world's bird species occur in South America (and over a fifth of the world's birds occur nowhere else), much of the continent is still without field guides. Getting a reasonably complete set of reference materials requires a bit of creativity. Wheatley identifies guides for neighbouring countries, and more general materials of use in such places.

Wheatley's acknowledgments make it clear that a wide net was cast to collect information for this book. Individuals and institutions with special insights into the sites have provided the author with considerable detail that would not otherwise be possible. It may be expected that the individual preferences and prejudices of the contributors will be reflected in some of the text. One such case is the Botanical Gardens of Rio de Janeiro, which receive a cursory and luke warm treatment. I loved the place. However, anyone with a wish to bird Brazil will now at least be able to find the site and have some idea of what to look for once there.

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Terns of Europe and North America

By Klaus Malling Olsen and Hans Larsson. 1995. Princeton University Press, New Jersey. 207 pp., illus U.S.$39.50.

This is a slightly-larger-than-pocket size book that will fit in a pack or the car. It contains chapters on 16 *Sterna* terns, three "black" terns, two noddys, and Gull-billed Tern. Each species is described in relatively non-technical terms that seem to be aimed at field use. This is followed by a second description in more scientific terms that appears to be useful for hand-held or closely observed birds. The descriptions cover six plumages from juvenile to adult. Information is also given to molt, geographic variations, and measurements. Each species is illustrated by colour plates showing standing and flying birds. Inset illustrations show special features such as bill size or tail pattern. The last section of the book is a series of 208 photographs, each one being about seven by seven centimetres.

I have a mixed reaction to this book. I was hoping for detailed reference work that gave much more information on plumage of juveniles, individual variations, and other useful field material than is available in existing guides. This book does provide a wealth of detail but a careful examination reveals many problems. First there are technical difficulties. The first figure is of tern topography and uses terms that are standard for the feathers and soft parts. The text however uses non-standard terms like "wrist" or "hand", which I found confusing. Other problems include using a word like "cold" to describe a yellow bill or saying a bird has a "virile . . . emphasis" are difficult to follow and probably arise from the translation into English. The language on some of the insert figures showing specific features is hard to follow. Figure three, showing juvenile tertials of Sandwich, Gull-billed, and Cayene Terns, is the worst. I am still not sure I am interpreting this figure correctly and I have tried six times as the wording is unclear. There are discrepancies between the text and plates. For example the Royal Tern is stated as looking more pale winged than the Caspian yet there is no discernable difference between the plates. The description of the juvenile Arctic's bill and the plate do not match. On the Common Tern plate the captions for nominate race and the *longipennis* race are switched and there are spelling mistakes like Ro*a*seate.

I do not like the illustrations. Most of the birds look like they are hunched against a cold wind and have lost the elegance that characterize terns. A number of the colours are not the correct shade and I do not think this is a printing problem. For example, the bills on the flight plate of the Common Tern are too orange while the Forster's are not orange enough. The important and well known wing pattern differences between the Common and Arctic terns are poorly illustrated.

Each species section begins with a general discussion of the bird and the species with which it might be confused. In some cases I felt these initial descriptions fell a little short. For example, I felt the discussion of differences between Arctic and Common terns needs to be strengthened. Also, there was no mention of potential confusion between Bridled and Sooty terns, a mistake I have seen made several times.

While this book does have much that is useful, the purchaser has to be knowledgeable enough to pick out possible errors and omissions. A skilled North American birder would find it useful in Europe and vice versa. The novice might do well to wait until the revised edition is published. The type size varies and in some places is very small so some people with eye problems may have difficulty in reading parts of this book. A thorough revision, especially of the plates would allow this book to live up to its promise. Meanwhile you might fare better with the original language version.

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Cadborosaurus: Survivor from the Deep

By Paul H. LeBlond and Edward L. Bousfield. 1995. Horsdal & Schubart Publishers Limited, Victoria, British Columbia. x + 134 pp. illus. $9.95.

Don't be totally mislead by the positive title or the very lurid cover — a richly red-eyed, giraffe-horned, impressionistic rendition by the talented artist Susan Laurie-Bourque. This is a relatively conservative, and very readable, account of the plethora of reports, particularly those from the British Columbia coast, of a strange and, until recently, undescribed marine creature; but one which will still remain highly hypothetical to many readers.

The text is the culmination of a crusade vigorously championed in a seminar presented by Bousfield at the Canadian Museum of Nature in 1992, later summarized in *Sea Wind* (6(3): 29–33 "Sea Monsters in Western Canada" E. L. Bousfield. 1992), and given at the annual meetings of the American Society of Zoologists at Vancouver, British Columbia, 29 December 1992. Both authors

hold Ph.D.'s, are Fellows of the Royal Society of Canada, and have distinguished records of scientific contributions in their own specialities far from the subject here. LeBlond has long been intrigued with reports of unidentified large marine creatures and earlier authored a compilation with J. Siebert (1973. Manuscript Report 28, Institute of Oceanography, University of British Columbia). He is currently director of the Program in Earth and Ocean Sciences at the University of British Columbia, Vancouver. Bousfield was, in succession, Dominion Curator of Invertebrates, Chief Zoologist, and Senior Scientist at the National Museum in Ottawa, and, until recently, Researcher Emeritus with its successor, the Canadian Museum of Nature. He has been affiliated with both the Royal Ontario Museum, Toronto, and the Royal British Columbia Museum, Victoria. He has an outstanding and continuing lifetime publication record in amphipod systematics, is a Past-President and Fellow of the Canadian Society of Zoologists, Honorary Member of The Ottawa Field-Naturalists' Club, and Managing Editor (and founder) of the systematics journal, *Amphipacifica*.

Eight tightly written and abundantly illustrated (sketches, photographs, graphs, and tables) chapters cover early evidence from Indian mythology and artifacts, subsequent sightings by European residents from 1881, and the burst of press coverage in the 1930s which continues to the present, although more than halved in 1960-1994 from its peak during 1930-1959. The book then turns to the scanty physical evidence, carcasses washed up on the beach (which usually were identified as something previously known when examined by the knowledgeable), the critical specimen found in July 1937 in a sperm whale stomach at the former processing station at Naden Harbour, Queen Charlotte Islands, and two descriptions of possible young. Nicely balancing the other material, the following chapter examines a host of "jokes and hoaxes" with cartoons of varying quality from newspapers of the time. The final three chapters examine what *Cadborosaurus* might really be, other reports of possibly similar creatures elsewhere in the world, and what the future might turn up. An appendix gives 178 accepted sightings (these data are used in summary in Figure 13, page 27; Table I, page 74 and Table II, page 76, where the totals are given as 181, 182, 182, respectively). Another lists 11 strandings or captures (8 of the latter examined and identified by the variously qualified as whale, shark, or sea lion remains). Six pages of chapter footnotes, a bibliography of 36 references, and a three-page index (the latter mainly to people mentioned in text as observers or authorities) conclude the book.

Particular tribute is noted to Bernard Heuvelmans (1968. *In the Wake of Sea-Serpents*. Hill & Wang, New York) as "the father of cryptozoology" [Heuvelmans. 1982. What is cryptozoology?. *Cryptozoology* 1: 1-12], and to Captain William Hagelund [1987. *Whalers No More*. Harbour Publishing, Madeira Park, B.C.] for his detailed description of a presumed juvenile. Also singled out is the debt to the late *Victoria Daily Times* editor Archie H. Wills, who in the 1930s and 1940s, during a circulation war with the then rival *Victoria Colonist*, championed publicizing reports of *Cadborosaurus* so successfully that they were taken up by papers as remote as New York, and to the late Dr. G. Clifford Carl, director during the 1940s to 1960s of the Provincial Musuem of British Columbia, a marine biologist by training. Both men kept extensive scrapbooks which have been available to the present authors.

Just before this book's appearance, the photographs of the Naden carcass were designated as the types in a formal description of *Cadborosaurus willsi* Bousfield and LeBlond (1995. *Amphipacifica* 1 (Supplement 1): 3-25). Purists regard this action as premature and argue that it should have been suspended in the absence of some surviving physical remains until new material is obtained and preserved. This is countered by the Bousfield and LeBlond contention that the form needed the attention now that only formal description could bring. In support of their conviction they have detailed here not only the evidence they believe valid, but also hypotheses on the creature's ecology and behaviour that follow from it, for all colleagues and the public to judge.

This book may be equally enjoyed by believers and nonbelievers alike. It should have a place on the bookshelves of both.*

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*Continuing interest in the topic has resulted in the formation of the "Caddy Club" in Victoria (C.C. Newsletter Number 2, dated 18 December 1995). Contact Dr. E. L. Bousfield, 611–548 Dallas Road, Victoria, British Columbia V8V 1B3. Phone (604) 380–3787.

Rogue Primate: An Exploration of Human Domestication

By John A. Livingston. 1994. Key Porter Books, Toronto. ix+229 pp.

The founding metaphor of this book is the idea that since both People and late 20th century domestic Cattle live under human order, mankind must be as degraded as the Holstein cow. Domestication has dulled the senses and reduced the independence of some ungulates and birds, so it must have done the same for People, who have developed language, culture, technology, and civilization as a "prosthesis", to help them along in the absence of the wildness that sharpens the lives of other species. These prostheses have caused ecological disaster because the domesticated loss of a sense of place has led to callous ecological abuse by Commercial People and their domestic and feral surrogates.

This is an interesting metaphor, but a metaphor must be more than interesting if it is to be used as an explanation of widely diverse phenomena. Holsteins may have lost freedom and wariness (reduced brain size is a zooarchaeological criterion of domestication not mentioned here) but the domesticates and inquilines of social insects are not considered, nor are other classes of symbionts and parasites that have lost social skills or sensory acuity. Certainly the social insects can be considered self-domesticated, and have had ecological effects comparable to those of People.

The reader's confidence is further shaken by careless errors. The ability to produce "fertile offspring" (page 26) is not sufficient criterion of conspecificity. Albertans will be astonished to learn that the "world distribution [of Rats] coincides with our own" (page 42). The megafaunal extinctions of the Pleistocene cannot be distinguished from those of previous ages because "species vanished *without replacement*" (author's italics, page 48); the commonly cited recovery time from a mass extinction is 10 million years. If the dinosaurs perished from an asteroidal impact it is scarcely plausible to calculate that they became extinct at the rate of one species per 1000 yr (page 51).

Livingston inverts the expression "hunter-gatherers" to "gatherer-hunters" because he thinks that gathering netted more calories than hunting; there are no rules for ordering such compounds in English, but adjectives precede the noun, so he may achieve the opposite of his intended reform. Joyce Cook assures me that the meat of Galapagan Goats is not unpalatable (page 46), but the entire book is prepared to believe any evil rumour about Goats and ignores the traits of Goats in catalogs of the characteristics of domestic animals. The contention that "human attacks on other humans . . . perhaps invariably . . . involve . . . 'pseudospeciation' . . . the use of violence toward one's own species of a sort which would normally be reserved for use against other species . . ." (page 55) is a forced metaphor, compromised by the frequency of spousal murder, where conspecificity is often proven by the criterion of fertile offspring.

Like many other authors, Livingston assumes that human mentality has been a constant through historic and prehistoric time. He fails to appreciate just how labile the "domestic" mentality is: one need not follow Jaynes all the way in the hypothesis of the bicameral mind to reflect on the religious, social, and intellectual mores of past generations — the uncoerced despotism that built the Pyramids, Amos' hallucinated moral strictures, the ages before Playfair, when data were never visualized in graphs, one's grandfathers' willingness to march off to the Great War — and realize that the global ecological awareness of a late 20th century Canadian naturalist is a novelty in human history. It may not seem that we are making much progress against commercial society, but our mentality is only 150 years old, and we cannot tell how fast it is spreading or what effect it may ultimately have.

Livingston repeatedly discredits misused scientific findings by mis-statements of scientific methods. The contention that "there is something tautological about the concept of niche … because a niche exists only when it is occupied." (page 67) fails to distinguish between the niche of a species (its role in a community, visualized as an occupied volume in a multidimensional space of ecological variables), and the niche space itself (the variables). To attack the concept of "pecking order" (and analogous dominance heirarchies in many species) by contending that most interactions among a flock of Chickens do not involve the combat needed to demonstrate the existence of the pecking order (pages 78-79), misunderstands the scientific method of making underlying order evident in artificial experimental situations.

This entire century has been a banner-headlines proclamation that it is inappropriate to take scientific findings too far, but surely this is a confirmation of the scientific belief that all knowledge must be checked against the real world, rather than a mandate for wild extrapolation of metaphors across the whole of society and nature. Livingston inveighs against mechanistic and market-like models of scientific natural history without asking about their history, or whether these are the findings biologists would have preferred. I suspect that biologists share his biases and devote disproportionate effort to the study of "co-operative" behaviour whenever they find evidence of it. Only in the past 50 years has biology been free from the wraith-like emergence of vitalistic hypotheses, and co-operative breeding by birds,

for example, is studied out of all proportion to the amount of food aunts and uncles carry to nieces and nephews.

There is no question that bad science and technology parasitic on science have contributed to the despoilation of the Earth, but this book is flawed advocacy rather than the kind of cooperative generous enterprise that Livingston would have the World become. We don't have here any hypothetico-deductive Darwinian humility before the facts, but a Platonic full-speed-ahead reasoning from slender first principles. Science works because it abases its theories before the real world of locality and history every step of the way, and it is more generous to an opponent's ideas than to its own. "The Monkey-bred brain can do no more than this: than to know when its tales go awry." Our arguments must embody their meaning in their form. A reformed way of knowing must shake off arrogant universalism and touch down in the real world at every step, and we must do this by going through and beyond Science rather than retreating to some supposed Nirvana of prehuman wildness which is not only impossible to recreate but probably never existed.

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BOTANY

Invasive Plants of Natural Habitats in Canada

By D. J. White, E. Haber, and C. Keddy. 1993. Canadian Museum of Nature, Ottawa. 121 pp.

Invasive Plants of Natural Habitats in Canada is meant to be a summarization of existing information regarding invasive plants in wetland and upland natural habitats. The authors arranged their information in two sections. The first provides a review of invasive plants in wetland and upland habitats. The second examines legislation which may apply.

The report is not meant to be an exhaustive look at the literature and is not. The species are interesting and I am surprised at a few which were not included. I am also puzzled by the method which was used to develop the ranking. The authors concede possibly a disproportionate representation for the Ontario region but fail to say if all replies to their survey had equal weight or if the answers were weighted according to region. If answers were given equal weight then Ontario's concerns may overshadow other regions' concerns. Restoration of natural areas as a source for increased threat of invasion of natural habitats, I feel, could have used greater emphasis. The authors note present legislation does not deal with natural areas specifically. The result is a suggestion for greater vigilance and increased human resources if legislation were changed to have a greater impact on natural habitats, an interesting problem in times of decreasing budgets and personnel.

The report provides a quick introduction to the problem of invasive plants in native habitats. One is able to grasp some of the complexities of the problem. The reader is also left with the feeling further investigation and effort are required by society to deal with this problem if not to solve it then to prevent its continued growth. For the report to be kept current, as the authors state, revisions will be needed as new data becomes available.

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Guide to Flowering Plant Families

By Wendy B. Zomlefer. 1994. University of North Carolina Press, Chapel Hill and London, XIV + 430 pp., illus. Cloth U.S. $55.00; paper U.S. $27.50

Students of botany, whether beginners or seniors, as well as professional botanists will welcome this most useful volume. In it they will find comparative information on each of 130 vascular plant families which are found in North America north of the Mexican border. For each family there is a good description, family characterization, estimated number of genera and species, general distribution, a list of the major genera with estimates of their number of species, the number of genera and species found in the United States and Canada, economic plants and products, a general commentary, and a bibliography. All this represents a tremendous effort but what is really unique is that adjacent to each family text is a series of line drawings of part of a plant, flowers, flower parts, fruit, and seeds by the author. Throughout the volume are 22 tables which can be used to distinguish between related families, another most useful contribution.

Over 300 additional small drawings by the author are to be found in the glossary, illustrating various

terms found throughout the text. These are not just sketches but accurate drawings of parts of a particular species so that the user can readily discern the part, e.g. *beak*: A long prominent, and substantial point, in particular, applied to prolongations of pistils/fruits, (25. *Sagittaria lancifolia* [Alismataceae]: achene with pronounced beak).

Two appendices and an index complete the book. Appendix A compares Cronquist's classification system with the classification by Thorne which is used by the author in this work. Appendix B is a "Family Summary Chart" where the families are in alphabetical sequence. In the latter one can quickly discern the number of genera and species in a family, distribution, vegetative habit and leaf shapes, floral aspects, fruit type and other important morphological features.

The author is to be congratulated for having produced this most welcome contribution to the study of vascular plants.

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Plants of Coastal British Columbia including Washington, Oregon, and Alaska

Compiled and edited by J. Pojar and A. MacKinnon. 1994. Lone Pine Publishing, Edmonton, Alberta. 527 pp., illus. $24.95.

This attractive, well-illustrated book has been written by a team of 10 talented naturalists: Paul Alaback, Joe Antos, Trevor Goward, Ken Lertzman, Andy MacKinnon, Jim Pojar, Rosamund Pojar, Andrew Reed, Nancy Turner, and Dale Vitt. The editors have done a good job of presenting everything in a smooth and easy to follow format.

As the list of additional reading will testify, this is certainly not the first book to appear on the plants of the area but it includes much that is in the other sources and thus a naturalist, photographer or other user can venture out with one book instead of an armful. There has been a need for some time for a single book dealing with the commoner plants of the area and this book fits the bill. Its compact size, quality paper, and sturdy spine also mean that it can be easily and safely carried in a backpack.

After an informative introduction and list of additional reading, this well written, easily understood, and interesting book is logically divided into color coded sections dealing with trees, shrubs, wild flowers, aquatics, oddballs, graminoids, ferns and allies, mosses and liverworts, and lichens. The text for each included species is accompanied by a map showing the general distribution in coastal British Columbia and adjoining areas, one or more color photos, and one or more line drawings. These illustrations are well done and in many cases are outstanding. There is a helpful list of Additional Reading sources, a good Introduction which deals with aspects such as the vegetation of the area and ethnobotany, a Glossary, and a list of References Cited. It is really quite amazing how much information has been included.

A weakness of this book is that it plays down the fact that many species found in the region are not mentioned. According to a statement on the back cover, 794 species are featured but nowhere is there a mention of the considerably larger number of flowering plants, ferns and fern allies, mosses, liverworts, and lichens that actually occur in the area. The addition of a checklist of all species known from the area, with highlights on those featured in the book, would have partially remedied the problem. Surely the comment "for both amateurs and professionals" was made partially tongue-in-cheek.

The fact that only one scientific and one common name are mentioned for each species will occasionally cause problems for those trying to cross reference with other books. A limited number of synonyms could have easily been included, such as *Platanthera* (=*Habenaria*) and *Sanguisorba* (= *Astragalus*). While common names are widely used and quite helpful with higher plants they are seldom used for bryophytes and lichens, and not many have wide acceptance. Many feel that it is best to refer to species of these groups by their scientific name alone. Lone Pine's decision to give common names to all included species has meant that a number of new names have had to be created. Many of these are novel and lack meaning and one seriously wonders about the applicability and usefulness of ones such as "waxpaper lichen" and "pimpled kidney".

This first-rate field guide to the plants of the coastal northwest deserves to be on the book shelf of all field-naturalists interested in the area. It should, however, not be depended upon by itself as a source for critical determinations but as a companion for more technical works covering all of the species of the region, such as Hitchcock's *Vascular Plants of the Pacific Northwest*.

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The Lichens of British Columbia: Illustrated Keys, Part 1: Foliose and Squamulose Species

By Trevor Goward, Bruce McCune, and Del Meidinger. 1994. Province of British Columbia, Ministry of Forests Research Program, Victoria, British Columbia 181 pp., illus.

Most of the current lichen books available are keys based on chemical and microscopic characteristics. These publications cannot serve the needs of the average field naturalist, let alone the growing number of amateur lichen enthusiasts.

This new guide to British Columbia lichens is different: serious but not technical, with illustrated keys designed to give — in the authors' words — "more or less equal weight to phylogenetic relatedness and morphological similarity". The authors assume — and rightly so — that most naturalists want to avoid using TLC (thin-layer chromatography) and PD (paraphenylenediamine, a reagent) to identify lichens. Goward et al. encourage lichen identification based on visual appearance and form, a return to a time-honoured and traditional approach that worked very well indeed. I cannot imagine a biologist, ecologist, naturalist, or a teacher anywhere in North America who could not pick up this book and *immediately* apply names to lichens.

Goward's illustrations of *Umbilicaria* spp. and *Peltigera* spp. are the finest I have seen, and far more useful than the photographs in Hale's popular *How to Know The Lichens* (1979). But while I am extremely impressed with this book overall, I must nit-pick where common names are concerned. Here is what the authors *themselves* have to say on this sore point. "Although many lichenologists (including the second author) resist the coining of common names, others (including the first author) feel common names are prerequisite to the popularization of lichenology". Does Goward (in particular) seriously believe that the cause of lichenology can be advanced by coining names like "forest speckleback" for *Punctelia rudecta*? (I've worked with eight year olds who can say *Actinogyra*.) But if Goward is right, then common names must be applied correctly. The authors give "corks" as one traditional name for *Parmelia omphalodes* and *P. saxatilis*; in fact, "cork" (minus the "s") is the correct name for *Ochrolechia tartarea*, a crustose species not covered in this book.

Most of the few Canadian lichen references available are diagnostic keys (*Lichens of the Ottawa Region*, Brodo 1988; *Lichens of Fundy National Park*, Gowan and Brodo 1988). These are indispensable, but the naturalist will find Goward et al. more "user friendly" in the field. Despite adequate photographs in some guides (Vitt, Marsh and Bovey's *Mosses, Lichens & Ferns of Northwest North America*, 1988), a growing number of botanists prefer top-notch drawings. Compare the price of Goward et al. with Thomson's *American Arctic Lichens: The Macrolichens* ($125 US), and it becomes clear that *The Lichens of British Columbia* (Part 1) is a bargain. Why not buy two copies — one for the library and one for the field.

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Exploitation of Environmental Heterogeneity by Plants: Ecophysiological Processes Above- and Belowground

Edited by Martyn M. Caldwell and Robert W. Pearcy. 1994. Academic Press Inc., San Diego. 429 pp., illus. U.S. $89.

There has been a growing interest in the ability of plants to adapt to a wide variety of conditions. *Exploitation of Environmental Heterogeneity by Plants* attempts to provide a synthesis of plant responses above and below the soil surface to this variety of conditions.

The editors utilized a world wide authorship of experts for the chapter reviews. The reviews themselves are technical in nature with a common scientific format. They are arranged with an equal number dealing with above- and belowground heterogeneity. The above ground chapters dealt with the light environment and plant responses to exploit various environments. The belowground chapters dealt with nutrient and water patterns and the subsequent plant responses. Of particular interest to this reader were the chapters dealing with geostatistics and the theory that slow growing plants may be more adept in utilizing a variable environment.

The book provides reference lists after each review and an index at the end. Figures were easy to read and utilize. There were a few minor typographical errors.

Martyn Caldwell and Robert Pearcy have provided the reader with a well organized and valuable source of information in this field. *Exploitation of Environmental Heterogeneity by Plants* does provide a synthesis of plant responses above- and belowground. The book will be of significant value to those with a technical background in the fields of ecology, agronomy, forestry, and plant physiology.

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Scientific and Common Names of 7000 Vascular Plants in the United States

By Lois Brako, Amy Y. Rossman, and David F. Farr. 1995. Contributions from the U.S. National Fungus Collections 7: 1–295. The American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, Minnesota 55121-2097. 294 pp. U.S. $29 in U.S.A.; U.S. $36 elsewhere.

For anyone who needs to know the common name or names of a plant when they have been provided with a scientific name, or vice versa, this will be a most useful book for vascular plants that occur in the United States and adjacent Canada. The common name for a particular plant may vary over time and region and in this volume one, or in some cases up to 13 common mames for each of some 7000 vascular plants can be found.

The book is divided into four sections. The first comprises a list of scientific names in alphabetical sequence by genus. The second is a list of common names followed by the accepted scientific name. The third is a list of synonyms of accepted scientific names, and the fourth is an alphabetical list of families in which an alphabetical list of genera is found after each family name.

This does not mean that all the vascular plants in the United States have common names. A quick search of several recent floras has revealed this. The missing ones however may only have a small range or may be difficult to find. The scan also revealed that some common names were not found during the compilation. This work will, however, still prove useful for those need to know an accepted latin name for a particular species or vice versa.

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ENVIRONMENT

The Masked Bobwhite Rides Again

By John Alcock. 1993. University of Arizona Press, Tucson. 186 pp., illus. Cloth U.S. $35; paper U.S. $16.95.

The Masked Bobwhite Rides Again is part of a new generation of ecological treatises that zero in on a particular habitat from different perspectives, but end up with the same basic message: that mankind's activities have seriously threatened, if not irreparably altered, the natural environment of the region and that immediate corrective steps are necessary or the uniqueness will be lost forever.

In this case, the aggrieved landscape is the Sonoran Desert of central Arizona, the adopted home of animal behaviourist John Alcock. Drawing upon his extensive field wok in the area, Alcock provides an intimate portrait of the desert that is part biogeography, part Aboriginal history, and part philosophy — all rounded out with a healthy dose of outrage. He describes the natural life of the region and its peculiarities, briefly reviews the history of Indian-government relations, and bemoans the destruction caused by cattle grazing on public lands. The best sections of the book, however, are those dealing with Alcock's reflections on the region — what he sees and the feelings he experiences during his many hikes; he truly has an abiding love for the desert.

The Masked Bobwhite would have greatly benefitted from a map of the Sonoran Desert, as well as some photographs. But these are minor quibbles. The strength of the book lies in its clarion call to *in*action: that the natural life of the region, in all its richness and diversity, has value in and of itself, and that it will recover and flourish — if left alone.

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Size and Integrity Standards for Natural Heritage Areas in Ontario

Edited by Scott F. Poser, William J. Crins, and T. J. Beechey. 1993. Proceedings of a Seminar. Parks and Natural Heritage Policy Branch, Ontario Ministry of Natural Resources, Huntsville. vii+138 pp., illus.

The Natural Heritage of Southern Ontario's Settled Landscapes: A Review of Conservation and Restoration Ecology for Land-Use and Landscape Planning

By John L. Riley and Pat Mohr. 1994. Technical Report TR-001. Ontario Ministry of Natural Resources, Southern Region, Aurora. 78 pp., illus.

The facts are all too well known: humans are changing the ecosphere at an unprecedented rate. In southern Ontario over 70% of the forests and wetlands and over 99% of the prairie environments are gone. And yet there are signs of hope. In the last 20 years the amount of woodland has actually increased.

Ecological integrity requires the systemic integration of "islands" of natural areas with the surrounding ocean of developed areas. *Size and Integrity Standards for Natural Heritage Areas in Ontario* assembles 11 papers presented at a one-day seminar held in 1992 to address this vital issue. The papers cover a variety of topics, including reviews of issues in conservation biology, case studies of management in provincial parks, and innovative uses of remote sensing technology to study forest fragmentation. The papers are uneven in quality and there is necessarily some overlap of material, but overall the papers provide brief introductions to research on and management of fragmented ecosystems.

The Natural Heritage of Southern Ontario's Settled Landscapes attempts to integrate these themes into a coherent view. It provides both the theoretical background and management guidelines for developing a natural heritage strategy. It is extraordinarily refreshing to encounter a government document that reads like a primer on conservation biology and fragmented ecosystems rather than a bureaucratic exercise in rhetoric. This otherwise excellent document is marred by a reference section that is not always in order and is missing some references cited in the text. Nonetheless this is an important publication in the history of ecological management in Ontario.

Both these documents are available free of charge from the government of Ontario. *The Natural Heritage of Southern Ontario's Settled Landscapes* should be essential reading for all those truly interested in the larger issues of conservation. Although the examples are all from Ontario, the principles are wisely applicable.

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Shield Country: Life and Times of the Oldest Piece of the Planet

By Jamie Bastedo. 1994. Komatik Series, Number 4. The Arctic Institute of North America, University of Calgary, Calgary, Alberta. viii + 271 pp. illus., $20.00.

Flying the Great Circle route from Edmonton to England, one passes over the Canadian Shield, an immense expanse of bare rock, blue lakes, conifers, and tundra, stretching across the northern half of Canada. Typified by the Tom Thomson painting of a stark pine-tree silhouetted against a lake, Shield country is inextricably entwined in the Canadian psyche, forming part of our image of ourselves, even for southern city folk who rarely visit the region. Out of his fascination and love for this compelling landscape, Jamie Bastedo has written an introduction and field guide to his part of the Shield country — the western "taiga shield" ecozone. This subarctic region, stretching in a broad band from the western shore of Hudson Bay to the eastern shore of Great Bear Lake, comprises the northern boreal forest margin. In an ambitious project, Bastedo surveys the geology, human history, climate, natural history, and ecology of the region in a very personal account, drawing on his own experiences and explorations.

Following an introduction, this book is divided into three main sections, containing 23 chapters, followed by notes, a glossary, a reference list, and an index. The first section, "The Making of the Landscape", comprises seven chapters surveying the geological and human history of the Shield, concentrating mainly on the central area around Yellowknife, the author's home. Bastedo points out that the Canadian Shield is not a homogenous geologic region but displays considerable diversity in lithology and structure. Worn down by tremendous intervals of erosion, the Shield contains the roots of vanished mountains and rocks dating back almost four billion years. Plutonic and metamorphic events emplaced mineral deposits in the Shield rocks, including the gold deposits that are in the *raison d'être* for modern Yellowknife. More recently, glaciation has stripped off the soil and most of the loose sediment, revealing the bare bones of the landscape, a *tabula rasa* for postglacial soil development and vegetation colonization.

Bastedo summarizes the human history of the western Shield, from the earliest archaeological evidence, in this region dating to around 7000 yr BP, through the Fur Trade era to the various mining booms of this century. Ruthless exploitation of the natural resources, generally by outsiders, has characterized the recent economic history of the Shield.

The physical difficulties of the landscape (poor soils, permafrost, long winters, mosquitoes, and blackflies) place real constraints even on modern settlement. Bastedo points out later that this will probably protect and preserve much of this landscape from development and maintain low human population densities.

The second section, "Today's Landscape", consists of two parts. Part I, "Threads in the Environmental Fabric", consists of seven chapters concentrating on specific aspects of the ecosystem. Winter is arguably the major physical factor in the North where, as the saying goes, the climate consists of "eight months of winter and four months of bad skiing". Certainly, winter and adaptations to severe climatic stress dominate Bastedo's discussion of the plant and animal life. Conifers are the most obvious Shield plant type and Bastedo outlines the physical and physiological characteristics that enable them to flourish here. He also surveys the other characteristic plants of the boreal forest, which include aspens, balsam poplar, birches, alders, willows, and berry-producing shrubs and forbs. Although not as noticeable as trees, lichens are an important component of the northern flora, clinging to bare rock surfaces and helping to provide a substrate for other plants.

Bastedo goes on to describe how mammals, such as caribou, lynx, and snowshore hare, can survive in snow-covered terrain. The fragility of their existence is indicated by significant cyclical population fluctuations. Some small mammals, such as voles, avoid winter as much as possible by living beneath the snow-pack. Others, such as bears, sleep through the worst weather in sheltered places. Bastedo points out that there are no true hibernators in the taiga shield. Bird life of the region consists of a nucleus of year-round residents, such as the grey jay and raven, an abundance of summer migrants, especially waterfowl, taking advantage of the short but productive summer season, and some winter visitors from the tundra, such as the ptarmigan.

Permafrost, insects, and fire are three other prominent elements of the Shield environment that Bastedo examines. As well as impeding plant growth, permafrost is one of the great challenges to construction and engineering projects in the North. Bastedo conjures up the torment for humans and animals alike induced by the profusion of biting insects during the summer. This chapter will provoke a wry smile from anyone who has worked in the bush. Finally, Bastedo shows that, modern attitudes notwithstanding, fire is an essential component of the Shield landscape, especially for controlling vegetation regeneration and patterns.

Part II of "Today's Landscape", entitled "A Tapestry of Habitats", consists of six chapters, each focussing on a specific habitat type. Bastedo uses descriptions of his own field trips and experiences to introduce some of the varied ecotypes of the region: bedrock, coniferous forest, deciduous forest, wetlands, rivers and lakes, and treeline. Most chapters contain species lists for plants and birds. Although at a cursory glance the country may appear monotonous, in these essays Bastedo shows clearly the small-scale complexity and diversity of the landscape. Each chapter can be read as a stand-alone essay. For me, these were the most enjoyable chapters of the book.

To round out his survey, Bastedo includes a concluding section "Tomorrow's Landscape", including two short speculative chapters attempting to assess the impacts of development, especially mining, and of environmental change, specifically global warming and ozone depletion, on the taiga shield region. Finally, he writes a plea for an understanding of this landscape. In many ways, this plea is by now redundant; Bastedo's whole approach has been to prove how an understanding of one's surroundings can lead to a richer personal life.

In this book Bastedo covers a vast amount of material from many disparate fields. I am certainly no expert in all the fields discussed but I did notice a few questionable statements. In the postglacial development of the Shield, for example, pollen records show that jackpine is a comparatively recent (mid-Holocene) addition to the boreal forest vegetation, not, as Bastedo implies (page 47), an initial colonizer of newly-deglaciated (early Holocene) terrain. J. C. Ritchie's book on *Vegetation History of the Far Northwest of Canada* (Cambridge University Press, 1984) would be a useful additional source for this discussion. Bastedo states (page 115) that larch is competitively disadvantaged in the spruce-dominated Canadian boreal forests. However, widespread larch forests do occur in eastern Sibera, where the climatic conditions are even more extreme. Another useful background reference for the vegetation chapter would be E. C. Pielou's *The World of Northern Evergreens* (Cornell University Press, 1988). I am curious about the source for the statement (page 47) that Hypsithermal summer temperatures in the taiga shield were up to 12°C warmer than present. Finally, the climactic Mazama eruption occurred about 6800 yr BP, not 5000 yr BP as implied in Bastedo's account (page 51).

The book contains a few line drawings, sketches, and many black-and-white photographs throughout the text with a separate gallery of colour photos. Generally, these are of good quality, although a few of the photos (e.g., pages 40, 96, 169, 173) would have benefitted from indications of scale. The text contains three maps, one showing the main ecozones, the second showing the main geologic subdivisions, and the third showing the extent of Glacial Lake McConnell. Surprisingly, because it is used as a point of reference throughout the text,

Yellowknife (and other settlements) only appears on the third map. I think this information should have been provided earlier for the reader unfamiliar with the area. The text is end-noted throughout; these end-notes are cross-linked to the reference list. The book is well-produced with very few typos. At only $20.00, it represents extremely good value for money.

Bastedo writes in a simple, straightforward style that should be easy to follow for readers unfamiliar with the subjects discussed. For the most part, Bastedo manages to avoid technical jargon and where he uses specific terms, he does explain them. Bastedo writes particularly well when describing his own experiences.

As are many potential readers of this book, Bastedo is a southern transplant to the taiga shield. If you are contemplating a visit to Yellowknife or if you are living in the region already, this book will serve as a good introduction to the fascinating Canadian landscape around you.

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Large-Scale Ecology and Conservation Biology

Edited by P. J. Edwards, R. M. May, and N. R. Webb. 1994. Blackwell Scientific Publications, Cambridge, Massachusetts. 375 pp., illus. Cloth U.S. $75; paper U.S. $29.95.

Large-Scale Ecology and Conservation is a collection of selected papers from the 35th annual symposium of the British Ecological Society. The symposium, and one assumes the book, had three objectives. "The first was to examine the nature of large-scale ecological processes, and the adequacy of ecological concepts and models to describe and understand these processes. The second . . . was concerned with practical problems of working at a large scale, and with special tools. . . . Finally, the social, economic, and political issues associated with the application of ecological ideas in decision making and policy were also considered." The editors arranged the chapters in much the same order the objectives were listed.

All papers were technical in nature and mostly based on studies undertaken by the authors of the individual papers. As a result the book provided a great deal of detail of methods used for collection, analysis, and presentation. Most authors made a point of mentioning potential future utilizations of techniques and information provided with an emphasis towards conservation biology. The final chapter had a message which is not new to ecology or the sciences as a whole. In this chapter the author stated scientists need to greatly improve their communication skills.

The book provided a good description of research and issues in large-scale ecology and how the knowledge can be applied to problems found in the field of conservation biology. The book met all objectives. I would recommend *Large-Scale Ecology and Conservation Biology* to those in, and interested in, the conservation and resource management fields of study and application.

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Biodiversity in British Columbia: Our Changing Environment

Edited by Lee E. Harding and Emily McCallum. 1994. Environment Canada: Canadian Wildlife Service, Pacific and Yukon Region, Vancouver. 426 pp., illus. $29.95 in Canada; U.S. $29.95 elsewhere.

This book should be welcomed by all British Columbia naturalists. The heart of the book is Part II: Species Diversity. Its 14 chapters give authoritative accounts of the current status in British Columbia of the whole realm of living organisms visible to the naked eye. The topics (authors, names in parentheses) are terrestrial and freshwater invertebrates (Syd Cannings); butterflies and moths (Guppy and Shepard); marine invertebrates (Lambert); Bryophytes (Schofield); lichens (Goward); macrofungi (Redhead); vascular plants (Roemer, Straley, and Douglas); seaweeds (Hawkes); reptiles (Orchard); amphibians (Orchard); freshwater fish (Peden); mammals (Nagorsen); birds (Dick Cannings); exotic species (Harding et al.) The last seems, at first thought, out of place but it is not. People should know which species should count as *non-species* when biodiversity is being assessed. The notion that weed species should be included in the calculation of biodiversity on the grounds that to exclude them is, somehow, "unscientific" needs to be exposed as preposterous.

The chapters listed above emphasize, as they should, rare, vulnerable, threatened, and endangered species, and their conservation. Conservation and biodiversity are, of course, inextricably bound. No doubt it is too late to abolish the ambiguous word *biodiversity* whose very existence is harming the cause of conservation because a few naïve ecologists have it muddled with *diversity*. The latter is a statistical parameter, invented in the 1940s, to aid the study of taxonomically restricted groups of species in small, homogeneous environments; it has nothing to do with conservation. The newer word, *biodiversity*, applies to the totality of living species in the whole world, and does have to do with conservation, that is, with the prevention of species being inadvertently driven to extinction by human action. The similarity of the words, and the sloppy abbreviation *diversity* for *biodiversity* perpetuates the misunderstanding; it is used in the titles of two of this book's parts and four of its chapters.

The book contains much else of interest. In Part I, Rowe writes a philosophical introductory chapter. Harcombe et al. deal with conservation terminology, explaining *red lists* and *blue lists*, and defining such terms as *vulnerable, threatened,* and *endangered*. Miller and Scudder explain the complexities of taxonomic nomenclature.

Parts III and IV, titled, respectively, "Ecosystem Diversity" (that word again!) and "Prospects for the Future" contain interesting "discussion" chapters, providing food for thought and argument. A conclusion I disagree with strongly is the editors', on page 236. Writing of declining caribou numbers, they say: "loss of old growth forest to timber harvest is permanent because [of the length of] planned harvest rotation periods . . ." Why *permanent*? Surely books such as this provide both the background information and the motive for abolishing unacceptable past practices.

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Principles of Conservation Biology

By Gary K. Meffe and C. Ronald Carroll. 1994. Sinauer Associates, Sunderland, 600 pp. U.S. $46.95.

Although they pursue similar objectives, applied ecologists and wildlife managers have generally worked in parallel, with little understanding of each other's methods and priorities. The discipline of conservation biology has contributed to the establishment of links between the traditionally theoretical perspectives of ecology and the applied traditions of forest and wildlife management. Conservation biology is a rapidly growing discipline, with its own scientific journals and now its own textbooks. The appearance of conservation biology courses in biology curricula is a sure sign of its increasing impact. Meffe and Carroll have compiled a comprehensive textbook to assist university professors in teaching this new discipline. The book is also accessible to naturalists interested in the concepts upon which conservation biology is based.

The book is divided into four sections: (1) introductory concepts, (2) population-level and (3) system-level theory, and (4) applications of conservation biology in land use and species management. In each chapter, essays by guest authors inform the reader on specific case studies, socio-economic issues or broad societal debates stemming logically from the subject-matter. Chapters end with discussion questions and an annotated list of suggested readings. The book also includes a fairly complete glossary of technical terms.

The authors have surrounded themselves with twelve guest contributors who provide a more in-depth treatment of specific areas. The tone of the book is decidedly holistic. The authors adopt a multidisciplinary perspective, tracing the philosophical issues that led to the development of conservation values and ethics. They discuss at length the interactions between ecological and socio-economic issues related to themes such as biodiversity conservation, nature-reserve design, policymaking, and global environmental change.

Meffe and Carroll provide a very thorough review of current issues such as policy implications of hybridization, spatially-explicit modelling of population dynamics, and the reestablishment of connectivity among nature reserves. However, several chapters could have been improved by a broader geographical perspective. For example, the chapter on ecological restoration ignores recent work conducted in western Europe, notably in the Netherlands, to recreate functional ecosystems. Policy issues are also strongly focused on United States, which is understandable considering that only one of the 14 authors or chapter contributors is based outside the United States. This geographical bias is somewhat offset by the short essays found in each chapter, but the focus does not extend far beyond the Americas. Another weakness involves the illustrations used in the book. The contrast in many of the black-and-white photographs is poor, reducing their effectiveness. However, graphs and maps are generally of high quality.

Advanced biology majors and masters students will greatly benefit from reading this book. It fits

well with smaller class sizes, where essays can be used to generate discussions that extend beyond the content of the chapters. The structure of the book is very well suited for teaching since most of the theory is concentrated in the first half. It also provides a solid theoretical basis for naturalists who are interested in applying some of their knowledge to specific conservation issues.

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Thinking Like a Mountain: Aldo Leopold and the Evolution of an Ecological Attitude toward Deer, Wolves, and Forests

By Susan L. Flader. 1994. University of Wisconsin Press, Madison. xxxii+284 pp.

Darwin and Wallace taught naturalists how to observe nature, and Thoreau taught us how to observe society's impact on nature, but Aldo Leopold was the first of the great literate naturalist-scientists to have the opportunity to direct landscape-modifying ecological policy. This reprint of a 1974 study traces the development of his ideas about the management of what is now surely the best-understood ungulate in the world, *Odocoileus* deer. He began as a young forester in Arizona and New Mexico in the 1910s, advocating predator extermination and refuges from hunting, and at the time of his death, in 1948, as a Wisconsin Conservation Commissioner, he was campaigning for increased hunting and protection for Wolves to preserve floristic diversity from over-abundant deer.

The "irruptions" of protected deer in these decades were the first unanticipated consequences of an over-successful ecological policy. Flader's enlightening account of Leopold's response to them reads like a carefully documented thriller, playing on the tension between Leopold's wholistic philosophical ideas, his knowledge or experience of changes in particular deer populations, and the inertia or perversity of public and political opinion.

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From Coastal Wilderness to Fruited Plain

By Gordon G. Whitney. 1994. Cambridge University Press, New York. 451 pp., illus. U.S. $54.95.

The sub-title, "A history of environmental change in temperate North America from 1500 to the present", is an accurate description of the contents, but the subtitle could equally well be "How not to settle a new country". Dr. Whitney is an Ecological Historian — a scientist who painstakingly tries to reconstruct what the natural world was like in the past, using travellers' narratives, Native North American oral history, as well as scientific analysis of lake sediment, tree rings, forest fire evidence and carbon dating. Ecohistory is important because, if we do not know from whence we have come, we cannot prescribe how to restore the ailing environment.

The author quotes European travellers' accounts of the landscape they found in the 17th and 18th centuries which are useful but unreliable, since few of the early explorers and settlers were naturalists or trained observers. Hence the "Lush, verdant forests as far as the eye can see" recorded by many writers is picturesque but upon investigation turns out to be false. One of several exceptions is Peter Kalm, a trained botanist sent by Linneaus from Sweden in 1772 to collect and catalogue the plants of the new world. His extensive papers are invaluable. Other reliable sources are André and Francois Michaux (late 18th and early 19th century). The devastation of forests was censured by many experts from the beginning of settlement. In Europe wood was harvested but forests were carefully maintained, whereas in the new world, there was little reforestation. Until the end of the 19th century house construction and heating was of wood almost exclusively, to say nothing of the voracious wood burning furnaces of the iron industry. Philadelphia required the equivalent of 11 square miles of forest to meet its needs for the 1826 domestic heating season.

In agriculture, the settlers did not even continue the established husbandry practices of European land use and domestic animal care when they came to North America. They practices "predatory agriculture' (von Liebig 1859), which is equivalent to the slash and burn method used by some farmers today in tropical countries, and much criticized. Many early settlers did not even use the manure from their animals to fertilize their fields, nor did they rotate crops. Another major influence on the agriculture, flora, and fauna of North America has been the

introduction of pests, disease, and alien species from other countries, but with the limited knowledge of earlier centuries, it was unavoidable. There are over 100 pages of references. The whole book is a model of clarity and is well written. It will be a valuable resource for researchers and students in a wide range of disciplines — environmentalists, naturalists, historians of early America, and promoters of sustainable agriculture. It is eminently readable by non-specialists for its own sake.

In spite of the damage to the natural world after three centuries, the author's forecast for the future is optimistic: ". . . we can use our knowledge of environmental change in the past to create a better future — a future that respects the land and its ecological constraints".

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Proceedings of the Thirteenth North American Prairie Conference: Spirit of the Land, Our Prairie Legacy

Edited by Robert G. Wickett, Patricia Dolan Lewis, Allen Woodliffe, and Paul Pratt. 1994. Thirteenth North American Prairie Conference. Department of Parks and Recreation, Windsor, Ontario. x + 262 pp., 30 illus. $30.00.

This volume is the thirteenth to be published in a series of biennial meetings, begun in 1968, which deal specifically with prairie ecosystems. The volume begins with the plenary lecture entitled "Sustaining the Circle of Life" and provides a fascinating philosophical overview of the symbiotic relationship that the aboriginal people have established and maintained with their environment for centuries. Following the plenary lecture, three papers effectively summarize the floral and faunal composition, ecological relationships, and management practices of the Ontario prairies and savannas. The majority of the volume consists of twelve papers in which specific aspects of the prairie flora and fauna are examined.

I was pleased to learn that considerable work has gone into documenting the flora and fauna of the tallgrass prairie, and that aspects of co-evolution and biotic inter-relationships are now being studied. While reading this volume however, I was overcome with the feeling of anger and frustration that we North Americans, as civilized and technologically advanced as we like to think we are, are no better than those who are cutting down the world's rainforests. Many of the plant and animal species endemic to these prairies are now rare and endangered, and some are extinct. How can we possibly assess the potential value of tallgrass prairie if we continue to develop these prairies for agricultural, industrial, commercial, and residential purposes? Two hundred years ago, tallgrass prairie was abundant. It is estimated that less than 1% of the original tallgrass prairie exists today, and what remains occurs in small disjunct patches.

Following the scientific papers is a series of papers in which a variety of prairie management strategies and the future of tallgrass prairies in modern society are discussed. While some of the management strategies presented showed signs of promise and practicality in restoration projects and management strategies, most were impractical, unrealistic, and expensive. I found the papers discussing management and development approaches for purely economic interests, to be out of place in a volume advocating the preservation and restoration of tallgrass prairie.

Although the value of this volume to science is minimal, it is significant in providing a number of useful floral and faunal listings and a better understanding of the complex interrelationships and co-evolutionary strategies that have evolved in the tallgrass prairies. Much more significant however, is the consensus among most authors that tallgrass prairie is rare and at the brink of extinction due to continued development and the inadequacy ot government regulations concerning the protection of these areas.

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A Practical Guide to Environmental Impact Assessment

By Paul A. Erickson. 1994. Academic Press, Inc., San Diego. 266 pp., illus.

As humanity continues to grow and advance conflicts of interest, society versus environment, etc. will likely become more frequent. The decision makers will require a tool such as environmental impact assessment to resolve differences. Paul Erickson wrote this book with the intent it be a "conceptual guide for those who have professional responsibility for the design, management, or conduct of impact assessment" to aid the decision making process.

The author focuses on how to identify, and evaluate impacts on all interdependent variables such as the physical and social environments. The book is well organized with four main sections: principles of environmental impact assessment, the physical environment, the social environment, and issues of special concern. Examples were used throughout to illustrate points. Procedural guidelines are also supplied. The book is not meant to furnish a complete literature listing but does provide an adequate list of further readings by chapter. The reader is also supplied with an index for quick reference.

The book deals mostly with the American situation but the information should be readily applicable to Canadian assessments. The author provides a practical guideline to the technical and scientific concepts which must be addressed during an assessment. This is a book I would highly recommend to professionals working in the field. If guidelines are followed as provided a valuable tool to aid the process for making better-informed decisions will have been provided.

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Nature's Kindred Spirits

By James I. McClintock. 1994. The University of Wisconsin Press, Madison. 147 pp. $23.50.

James McClintock has gathered his favourite authors on nature and conservation topics and presented them in a book which presents their truths and their lives as a review of nature topics and nature philosophy. Aldo Leopold (1877-1948), Joseph Wood Krutch (1893-1970), Edward Abbey (1927-1989), Annie Dillard (b. 1945), and Gary Snyder (b. 1930) are the writers whom he picked and whom he presents to us as the foremost thinkers and writers on nature topics in the 20th century. In general, all of the authors have a great knowledge and appreciation of the writings of Henry David Thoreau. The other common experience of the authors is the time each spent in solitary contemplation of the natural world whether wide ranging over many parts of the United States or one particular corner considering seasons, moods, and the influences past and present of ecological and human pressures.

Individually the experience and the philosophy of each author are widely divergent. Aldo Leopold was a conservationist who ranged widely over the U.S. as a forester, game management biologist, and apostate conservation bureaucrat. His sensitivities were with nature as a good in itself rather than a useful resource and he was a pioneer in thinking of nature that way. Using Leopold's writings, especially *Game Management* (1933) and *A Sand County Almanac* (1949) McClintock traces thought and themes through most of his life and work.

Edward Wood Krutch was different in thought, though borrowing heavily on Leopold as influence in his writings. Initially a professor of English and a drama critic with ambivalent thoughts on nature, he became first an appreciative of science and then a conservationist looking beyond science to see the order and creativity of the natural world. In his earliest nature writings he described himself as a pantheist, one who finds God as nature and all which is seen and present in the world. Later he revised his theology to described himself as a metabologist believing "*that life is not completely explainable in merely physical terms and that psychological, philosophical, moral, and aesthetic questions should be discussed in connection with what we know about living creatures*" (page 53). Science was the necessary touchstone for certifying truths about the natural world but larger world views and myths of spiritual experience grew from the scientific base. Scientists and philosophers as well as ideas from English literature were all influences in Krutch's thought.

The third writer, Edward Abbey, was a writer of fiction as well as a writer of nature essays. His spirituality was that of an antagonist to theology and organized religion but with a faith system in the beauty and transcending power of the earth itself, beyond normal science. Encounters with the desert and writing about those encounters brought him his own spiritual awakenings. He describes this spirituality as being an "earthiest". As a fiction novelist, his influences about the natural world and the philosophy of nature are drawn from other fictional writers, in particular Jack London, Robinson Jeffers, and B. Traven. His works are known in particular for humour which thinly masks an outrage at people's taking the natural world for granted.

Standing opposed to the theologies of the three preceeding writers, the fourth writer which McClintock picks is Annie Dillard, a modern upper middle-class woman who is an essayist, poet and teacher. Her background is Evangelical Christian and her preference became the rituals of the Catholic Church. Not only in worship but in relation to the natural world did her habits of prayer and ritual express themselves in her wanderings near Tinker Creek, a wilderness area near her summer home. Her meditative walks there became ritual stalkings, seeing and dancing with the animals and fish which lived there. By disciplining herself to be observant she was able to see much more of the nature at her feet than simply strolling in a beautiful setting. Her philosophy also drew on the writings of the ancient Greek philosopher Heroclitus, who identified opposites of joy and pain, beauty, and grotesque as well as good and evil. It is this spirituality of seeing the natural world which sets her apart as a naturalist vocally encamped in the spirituality of organized Christianity and comfortable with reconciling that faith with comment and challenge to our views of the natural world.

Gary Snyder is the last of the group. A poet, essayist, and environmental activist who is educated in anthropology, literature, and Zen Buddhism he brings all of these studies into his thought and philosophy. His thesis is that a person who wished to become a dweller in the land must understand two basic principles, "learn the flowers" and "learn the lore". The flowers are learned with one's intellect and also with one's body, commitment, time, labour, and walking. Like Annie Dillard, he stresses that walking is a spiritual practice, meditation, of sights and changes in the land. The lore of a place is the history and wisdom which the place has accumulated, including the human history but not exclusive to humans, for plants, rocks, and animals who dwell in the place have their lessons as well if we have the wisdom to study what they have to teach. Snyder follows the spirituality of the East which emphasizes a state of awareness and openness which is also experienced by animals, plants, and rocks, indeed the whole earth as a multi-cultural community.

McClintock begins with a quote from the prophet Ezekiel, perhaps showing us his own tradition and spirituality, "*Seemeth it a small thing unto you to have fed upon the good pasture, but ye must tread down with your feet the residue of your pasture? And to have drunk of the clear waters, but ye must foul the residue with your feet?*" (Ez 34:18-19). His choice of authors shows a need to combine good conservationist principles with spirituality and a doctrine of faith. Though some of the authors would react against the notion of a theistic belief system, in fact McClintock has shown that each had carefully adopted God and structured their beliefs whether previous to their writing careers or during the course of their work. His book is not easy to read and preknowledge of a lot of English literature as well as natural history and conservation literature is necessary to fully understand what he is talking about. It is a book which is good for the amateur conservationist to pursue on a free evening and could perhaps be a reference in a course in poetry covering natural history topics (if such a course existed). The book is available in Canada but it is subject to a 20% mark-up for importing academic literature which makes the final price of $23.50 rather steep for a small book.

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MISCELLANEOUS

Science in the Subarctic

By Debra Lindsay. 1993. Smithsonian Institution Press, Washington. xvii+176 pp., illus. U.S. $34.00

Subtitled *Trappers, Traders, and the Smithsonian Institution*, this book recounts the efforts of Spencer Baird, Robert Kennicott, and a network of co-operating local assistants to collect specimens of natural history along the Mackenzie River and in Alaska in the 1860s. During this time Baird, leading the Smithsonian with exemplary vision and energy, dispatched the young naturalist Kennicott and supported his endeavours.

Baird is well profiled as a collector, taxonomist, biogeographer, perceiver of the gaps in the collections of his Institution, and effective user of the governmental and military apparatus for its benefit. It was Baird who developed the standards for collecting, by a wide array of suppliers, initially in biology and by extension into anthropology. With his roots in Illinois and devotion to natural history, Kennicott operated along the Mackenzie with the approval and support of the Hudson's Bay Company and its Governor, George Simpson.

The acquisition of indigenous artifacts, and accompanying essays prepared by trader-collectors on-site, reflect both ethnological interest and outright racism. Lindsay indicates how the sources of

the specimens were induced and flattered with material benefit, memberships, prestige, and eponyms. While collections were richly reaped from north-west Canada, the efforts in Alaska were not as rewarding. In this latter region Kennicott was a scientific adjunct to an unsuccessful commercial expedition undertaken by Western Union (such are the hazards of sponsorship!) during which he apparently committed suicide. Regrettably, Kennicott is not as fully presented in the book as Baird.

In her conclusion Lindsay focusses on a labour analysis of fieldworkers as much as the history of science, and instead of other aspects such as political developments or personal motivations. Such an analysis is intriguing, but it could presumably have been strengthened by inclusion of other historical cases and of the contemporary case of parataxonomists, quickly- and narrowly-trained locals who are increasingly being employed in countries such as Costa Rica to collect specimens. Nonetheless, the history of Baird, Kennicott, and their assistants is well told in this book.

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Naturalist

By Edward O. Wilson. 1994. Island Press/Shearwater Books, Washington, DC. 380 pp., illus. US $24.95.

The down-to-earth and inspiring autobiography of a great naturalist, it made me want get outside and start observing! The choice of title is significant for a renowned researcher and theorist. Wilson recognized early in his career, as many scientists studying biodiversity are discovering now, that there is an important role to be filled by naturalists. Having weathered the storm of ridicule from famous reductionists such as molecular biologist James Watson (whom Wilson described as "the most unpleasant human being I had ever met"), he argues passionately that natural history has its place along side these more high-tech fields. Following a field trip to the South Pacific, Wilson published a technical paper describing patchy distribution of ant species in New Guinea rain forest. He states: "I felt gratified — indeed exuberant — that I had discerned what appeared to be a broad ecological pattern from my undisciplined collections and journals. But this was the way it is supposed to be. Nature first, then theory. Or, better, Nature and theory closely intertwined while you throw all your intellectual capital at the subject. Love the organisms for themselves first, then strain for general explanations, and, with good fortune, discoveries will follow. If they don't, the love and the pleasure will have been enough." My sentiments exactly, and very encouraging words to amateur naturalists. Wilson is also a refreshingly honest writer. While some authors seem to give examples of their own mistakes as springboards to show how much wiser they have become, Wilson states flatly: "I am a poor mathematician". Rather than make excuses, he came up with his own rule: ". . . for every level of mathematical ability there exists a field of science poorly enough developed to support original theory." As a developer of the theory of island biogeography (with Robert MacArthur), he seems to have proved his own rule.

Wilson has won two Pulitzer prizes and this book shows his writing skill. It is full of great descriptions of places, organisms, and events in his life. From the eye injury he received as a child from the spine of a fish, to his later championing of the need to preserve biodiversity, the book chronicles his life as a series of wonderful stories: a frightening close encounter with a large cottonmouth, a bite from a small rattlesnake, religious experiences as a junveile, his failed attempt to be a long-distance runner in college, ant collecting trips around the world, disputes with well-known colleagues. All are described in rich prose which made me eagerly read the book in a few sittings.

Finally, lest we be discouraged that all the great natural history discoveries have already been made by greats such as Wilson, he points out on the last page of the book that on the microbial scale there is still unmapped terrain "close to pristine and still unvisited" waiting for the next generation of natural historian explorers, all within ten feet of the building.

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From a Biological Point of View

By Elliott Sober. 1994. Cambridge University, Cambridge x+255 pp. Cloth US $59.95; paper U.S. $18.95.

It is a sign of the maturing of biology that its philosophy is now an established discipline. The author is one of its leading lights, and emphasizes his interest in relating this philosophy to logic and empiricism by taking his title after Quine's *From a Logical Point of View*. The volume consists of a dozen essays, three of them new, intended for philosophers and philosophically inclined scientists. Thus, in contrast to his previous books, this one is not aimed primarily at biologists, but instead considers specific and diverse foundational topics at an advanced level and draws extensively on the work of contemporary philosophical colleagues and Bayesian probabilistic analysis.

The possible evolutionary advantage of altruism over egoism is carefully examined in terms of levels of selection and of proximate and ultimate causation. The problems with solipsism, particularly its semantic fragmentation from which operationism also suffers and the need for theory, are analyzed, although only with difficulty since, as Sober notes, natural language seems committed against solipsism (and sensibly so!). Learning is examined in terms of functional advantages in an essay which refers remarkably little to experimental findings. The evolution of truthfulness and lying is compared with that of mimicry, adding to useful contributions on animal and human minds. The prospects for an evolutionary ethics (a hot issue indeed) are excellently reviewed in terms of the is/ought distinction, genetic arguments, and biological and cultural evolution. Two essays evaluate the relative merits of realism and empiricism, the (in)famous observation/theory distinction, and the non-essentiality of the principle of parsimony. They interestingly argue for a focus on problems rather than propositions, and draw on group selection and cladism as examples. Phylogenetic inferences and Mendelian rules illustrate discussions in three further essays on the principle of common causes, explanatory presuppositions, and temporally oriented laws. Two essays are especially germane, one dealing with essentialism and evolutionary populations, and the second with apportioning causal responsibility by applying analysis of variance to nature/nurture problems and so discriminating what statements are meaningful of individuals and of populations.

The arguments in each essay are cogent and presented in a clear style. There are many claims, such as the difference between fixed action patterns and behaviour triggered by beliefs, which lead to reflection and question. For those biologists interested in these basic issues (and that should be most of us!) and with an adequate background this book offers rich material.

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Minutes of Meetings 1924-1927 of the McIlwraith Ornithological Club, London, Ontario, Canada

By William W. Judd. 1994. Phelps Publishing Company, London, Ontario. iii + 95 pp. $10.00.

This is at least the 30th book pertaining to the history of natural history in southern Ontario published by W. W. Judd since 1969 and four more have appeared between the time of its publication and the end of January 1995. These books and numerous newsletter articles consist of biographies, bibliographies, minutes, catalogues of newspaper columns, memorabilia, and similar material, primarily (but not exclusively) from Middlesex County and surrounding areas. This is the fourth covering minutes of predecessors of the McIlwraith Field Naturalists of London, the first detailing the 1890-1903 meetings of the Entomological Society of Ontario, the other three detailing minutes of the McIlwraith Ornithological Club from 1915 to 1919, 1920 to 1923, and 1924 to 1927. One of the 1995 volumes extends these minutes to 1928-1931.

After a half-page introduction, the book starts with 68 pages of photocopied minutes handwritten by Margaret A. McKone, recording secretary of the time. The meetings covered have been numbered 118 through 148. These minutes cover club business, bird reports, accounts of meetings attended by members, accounts of talks given by speakers, conservation issues, identification tips, and even efforts to increase subscriptions to the *Canadian Field-Naturalist*. Minutes for specific meetings range from less than a page to about six pages. The remainder of the book consists of five appendices, the first three listing bird names, geographic locations, and people mentioned in the minutes. The fourth, on "comments on events and topics at meetings," is essentially a series of footnotes ranging from a sentence to a paragraph, with zero to four comments per meeting. The final appendix is a list of references, most of which are cited in the introduction or in one of the other

appendices. Details of some references are given where cited, rather than in this appendix.

Readers who enjoy browsing through writings of by-gone times will find numerous nuggets of interest within these minutes, such as a report of the first European Starling nest documented in the London area (page 19) and reports of activities of various naturalists of the era, both in London and elsewhere. The appendices provide the greatest value to historical researchers and seem fairly thorough, although at least one bird species (Lazuli Bunting) and one person (Hoyes Lloyd) mentioned in the minutes are omitted from the corresponding lists. The lists of people and geographic locations are annotated, adding to their value. Appendix 4 provides helpful perspectives on several topics, although more information might have been helpful on some. For example, the comment in the minutes that Lazuli Bunting is a species of the south is not corrected to indicate that it is a western species. The list of birds will be unfamiliar to younger readers with little knowledge of older names. Instead of using the latest (1983) checklist of North American birds and its subsequent supplements for this list or the 1910 edition in use at the time of the minutes, Judd chose the 1957 edition. In fact, 44 of the names listed deviate from that edition and the names used are those of various editions or even colloquial names, never used officially in two cases. It would be preferable to use current names, cross-referenced to those in use at the time the minutes were taken.

In spite of minor drawbacks, this book adds to Dr. Judd's impressive record of making rather obscure material more accessible to the growing number of naturalists interested in historical aspects of Canadian natural history.

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Darwinism Evolving

By David J. Depew and Bruce H. Weber. 1995. Massachusetts Institute of Technology Press. Cambridge. xiii+588 pp. U.S. $49.95.

From the pair who edited *Evolution at a Crossroads* for the same publisher nine years earlier, with which it shares affinitics, comes a book big enough to be both broad and deep for a major topic like the evolution of Darwinism. The subtitle *Systems Dynamics and the Geneology of Natural Selection* summarizes the intentions of the authors to provide a history of Darwinian evolutionary theory, especially the recent use of non-linear dynamical systems, for a broad audience. The Introduction provides a valuable framework for understanding the overall approach of the book within which Darwinism with its central concept of natural selection is seen as a very evolving theory influenced by key exponents, critical data, and events in other sciences and in society at large. Part I (Darwin's Darwinism) covers the history from Aristotle and his pre-Darwinian disciples through Darwin and his social and philosophical context to the reception of *Origin of Species* including its acceptance, rejection, and misinterpretation. Part II (Genetic Darwinism and the Probability Theory) traces the impact of work on ontogeny and phylogeny, and the emergence of the "modern synthesis" including Mendelism and population genetics. Part III (Molecular Biology, Complex Dynamics, and the Future of Darwinism) documents the impact of molecular genetics, developments, scales of analysis, and new models for complex evolutionary dynamics (for which the authors are enthusiastic but only time will tell if correctly so). Pertinent concurrent changes are explained, especially in physics, from mechanical through to chaotic frameworks, and major outstanding issues such as the relation of ontogeny and phylogeny analyzed.

The authors impressively demonstrate the signficant ontological changes through which Darwinism has passed. The most impressive feature of this book is the satisfying fullness of the contextual material within which the main story unfolds. Beyond excellent biographical material on a panoply of individuals, there is good interweaving of developments in philosophy of science (e.g. the influence of logical positivism and debates over reductionism), general intellectual history (e.g., the interactions of the natural and human sciences), and politics (e.g., the reforms of the British Whigs and American policy on immigration). The style of writing is polished and conversational, despite dealing with such complex issues as the description of organisms as "informed autocatalytic dissipative structures", and each part is accompanied by a useful Reading Guide. Overall this is a book well worth reading and considering.

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American Women Afield: Writings by Pioneering Women Naturalists

By Marcia Myers Bonta. 1995. Texas A & M University Press. College Station. 272 pp., illus. Cloth U.S. $35.00; paper U.S. $15.95.

Intended as a companion to *Women in the Field* (1991), Marcia Myers Bonta's newest book is lively, informative, and carefully assembled. Her focus on twenty-five American naturalists highlights their personal lives, their recognition within scientific and public circles, and their field methodologies. Although seventeen women who appear in Bonta's first book also appear in her second, there is little overlap. Because the book's rationale is to include women who were skilful writers as well as naturalists, eight new biographies have been added. Consequently, naturalists whose contributions may have been more important scientifically have been omitted owing to the hesitancy of their prose. Each chapter contains excerpts of original manuscripts, many of which are no longer available in libraries and are long out-of-print. A brief biography introduces each naturalist, followed by passages chosen for their material content and representative value. High quality photographs illustrate the texts.

Bonta wisely dispenses with problematic disciplinary classifications within Natural History, such as botany, ornithology, entomology, and arranges her women in chronological order by birth. This situates the woman historically and facilitates comparative work. For example, Susan Fenimore Cooper's celebrated *Rural Hours* (1850) was written four years before Henry David Thoreau's *Walden*, fifteen years before John Burrough's popular essays on birds, and in Canada, eighteen years before Catherine Parr Traill's *Canadian Wild Flowers*. While Bonta does not attempt to define the term "Nature Writer," a recent book by Frank Stewart, *A Natural History of Nature Writing* (1995, Island Press, Washington, D.C.) clearly attributes the creation of the genre to Henry David Thoreau, John Burroughs, John Muir, and Aldo Leopold. The evidence which Bonta presents should encourage readers to question this sweeping assumption.

Because women's nature writing was not confined to traditional journals or popular magazines, Bonta's excerpts have been gleaned from a wide variety of diverse periodicals. Modern day field-naturalists should find them particularly interesting, as many earlier studies done on plant and animal species have been either neglected or forgotten. Highlights include Anna Botsford Comstock's observations on the Basswood Leaf-roller, Ann Haven Morgan's essay on Mayflies, Elizabeth Gifford Peckham's writings on solitary wasps, and Althea Sherman's disturbing account of House Wrens. Annie Trumball Slosson's "Collecting on Biscaye Bay" is delightful, and Alice Eastwood's personal story of saving over 1000 rare botanical specimens from the San Francisco Academy during the 1906 earthquake is particularly inspiring. What quickly becomes apparent is the perseverance, dedication, and meticulous attention to detail which these women shared regardless of personal safety, adequate funding, or academic recognition.

Bonta has tried to include women working in different geographic regions (with the exception of Alaska) and her collection of publications date from about 1850 to 1960. A reading list concludes each chapter, and a closing bibliography cites other relevant scholarly work. While an index of names and places would be helpful, this omission is not serious and probably is due to restrictions on overall length.

The book's most important qualities are its readability and wide audience appeal. There is a great need to bring back historical literature of this kind. With the current emphasis placed on specialization in the life sciences by most academic institutions, few people will have ever investigated the significant works which naturalists and nature writers generated almost a century ago. Information, perhaps essential to our understanding of ecology, conservation, and environmental change, is needlessly collecting dust. Indeed, it's time to re-evaluate the older contributions afield.

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NEW TITLES

Zoology

†**Alberta butterflies.** 1995. By C. D. Bird, G. J. Hilchie, N. G. Kondla, E. M. Pike, and F. A. H. Sperling. Provincial Museum of Alberta, Edmonton. vii+349pp., illus. $44.95.

*__Atlas des amphibians et des reptiles du Québec.__ 1994. Par J. R. Bider et S. Matte.Societé d'histoire naturelle de la valle du Saint-Laurent et Ministère de l'environnement et de la faune du Québec, Québec. 106 pp., illus. $12.

The birds of South America, volume II. 1994. By R. S. Ridgely and G. Tu-Dor. University of Texas Press, Austin. xii+814 pp., illus. U.S. $85.

Birds of southwestern Australia: an atlas of changes in distribution and abundance of the wheatbelt avifauna. 1995. By D. Saunders and J. Ingram. Surrey Beatty, Chipping Norton, Australia. 304 pp., illus. A $39.95.

Birds of the pacific northwest mountains. 1995. By J. L. Wussink. Mountain Press, Missoula, Montana. viii+199 pp., illus. U.S. $14.

*__Cadborosaurus: a survivor from the deep.__ 1995. By P. H. LeBlond and E. L. Bousfield. Horsdale and Schubert, Victoria. x+134 pp., illus. $9.95.

†**Citizen's guide to migratory bird conservation.** 1995. By Cornell Laboratory of Ornithology, Ithaca, New York.

†**A complete guide to scientific and common names of reptiles and amphibians of the world.** 1995. By N. Frank and E. Ramus. NG Publishing, Pottsville, Pennsylvania. 377 pp. U.S. $19.95.

Dancing honeybees and other natural wonders of science: an illustrated compendium. 1994. By W. L. Baker. Contemporary Books, Chicago. 96 pp., illus. U.S. $9.95.

A field guide to Australian butterflies. 1995. By R. Fisher. Surrey Beatty, Chipping Norton, Australia. 254 pp., illus. A $29.95.

A field guide to Australian frogs. 1995. By J. Barker, G. Grigg, and M. Tyler. Surrey Beatty, Chipping Norton, Australia. c322 pp. A$34.95.

A field guide to the smaller moths of south-east Asia. 1994. By G. S. Robinson, K. R. Tuck, and M. Shaffer. Malaysian Nature Society, Box 10750, 50724 Kuala Lampur. 309 pp., illus. U.S. $35.

Identification guide to ant genera of the world. 1994. By B. Bolton. Harvard University press, Cambridge. 222 pp., illus. U.S. $65.

†**Illustrated guide to the birds of southern Africa.** 1993. By I. Sinclair, P. Hockey, and W. Tarboton. Princeton University Press, Princeton. 426 pp., illus.

Insects. 1994. By H. and M. Facklam. Twenty-first Century Books, New York. 64 pp., illus. U.S. $15.95.

†**A landowner's guide to prairie raptors.** 1995. By G.L. Holroyd, I. Shukster, D. Keith, and L. Hunt. Environment Canada, Edmonton. 48 pp., illus. Free.

†**Landscape approaches in mammalian ecology and conservation.** 1995. Edited by W. Z. Lidicker, Jr. University of Minnesota Press, Minneapolis. 216 pp. U.S. $35.95.

*__The last of the curlews.__ 1995. By F. Bodsworth. Counterpoint, Washington. 192 pp., illus. U.S. $15.

†**Lone star dinosaurs.** 1995. By L. Jacobs. Texas A&M University Press, College Station. 170 pp., illus. U.S. $27.95 (Canadian distributor UBC Press, Vancouver $39.95).

†**Mammals of the Canadian Rockies.** 1995. By G. W. Scotter and T. J. Ulrich. Fifth House, Saskatoon. Distributed by University of Toronto Press, Toronto. xi+185 pp., illus. $22.95.

†**Masters of the ocean realm: whales, dolphins, and porpoises.** 1995. UBC Press, Vancouver. 112 pp., illus. $24.95.

*__The minds of birds.__ 1995. By A. F. Skutch. Texas A&M University Press, College Station. 200 pp., illus. U.S. $29.95. (Canadian distributor UBC Press, Vancouver. $42.95).

*__North American/world birdarea.__ 1995. By Santa Barbara Software, 1400 Dover Road, Santa Barbara, California 93103. DOS disks + 61 pp. manual. U.S. $99.95.

The penguins: biology and management. 1995. Edited by P. Dann, I. Norman, and P. Reilly. Surrey Beatty, Chipping Norton, Australia. c482 pp., illus. A $85.

*__A photographic guide to North American raptors.__ 1995. By B. K. Wheller and W. S. Clark. Academic Press, San Diego.

Proceedings of the international symposium on genetics of subarctic fish and shellfish. 1994. Edited by A. J. Gharrett, W. W. Smoker, R. L. Wilmot, J. H. Helle, J. E. Seeb, and L. W. Seeb. Supplement 1, Canadian Journal of Fisheries and Aquatic Sciences. Alaska Sea Grant, Fairbanks. 340 pp. U.S. $25.

Reflections of a whale-watcher. 1995. By M. A. Gilders. Indiana University Press, Bloomington. xvi+269 pp., illus. Cloth U.S. $29.95; paper U.S. $16.95.

Reintroduction biology of Australia and New Zealand. 1995. Edited by M. Serena. Surrey Beatty, Chipping Norton, Australia. c276 pp., illus. A $75.

Seals and sea lions of the world. 1994. By N. Bonner. Facts on File, New York. 224 pp., illus. U.S. $25.95.

*__Summer atlas of North American birds.__ 1995. By Price, Droege, and Price. T&AD Poyser, Stote-on-Trent, England. 364 pp. £30.

Underwater guide: Mediterranean Sea fishes. 1995. By R. Patzner and H. Moosleitner. Naglschmid-Vertrieb, Stuttgart. 168 pp., illus. DM49.80.

Underwater guide: Mediterranean Sea invertebrates. 1995. By H. Moosleitner and R. Patzner. Naglschmid-Vertrieb, Stuttgart. 216 pp., illus. DM49.80.

Wild animals and settlers on the great plains. 1995. By E. D. Fleharty. 336 pp., illus. U.S. $27.95.

Botany

***Bromus* L. of North America.** 1995. By L. E. Pavlick. Royal British Columbia Museum, Victoria.

The classification of leaf venation patterns. 1995. By E. P. Klucking. Cramer, Stuttgart. 337 pp., illus. DM270.

***The desert grassland.** 1995. Edited by M. P. McClaran and T. R. van Devender. University of Arizona Press, Tucson. 352 pp., illus. U.S. $40.

Diatoms from British Columbia (Canada) lakes and their relationship to salinity, nutrients, and other limnological variables. 1995. By B. F. Cummings, S. E. Wilson, R. J. Hall, and J. P. Smol. J. Cramer, Stuttgart. iv+207 pp., illus. DM160.

Ericaceae - part II: the superior ovaried genera (Monotropoideae, Pyroloideae, Rhododendroideae, and Vaccinioideae). 1995. By J. L. Luteyn and collaborators. New York Botanical Garden, Bronx. U.S. $85.

Flowers of the canyon country. 1995. By S. L. Welsh. University of Utah Press. (Canadian distributor UBC Press, Vancouver). 103 pp., illus $22.95.

Fungi. 1994. By J. Tesar. Blackbirch Press, Woodbridge, Connecticut. 64 pp., illus. U.S. $16.95.

An illustrated survey of orchid genera. 1995. By T. Sheehan and M. Sheehan. Timber Press, Portland, Oregon. 169 pp., illus. U.S. $99.95.

Manual of grasses. 1995. Edited by F. Darke. Timber Press, Portland, Oregon. 250 pp., illus. U.S.$39.95.

†The Ontario naturalized garden: the complete guide to using native plants. 1995. By L. Johnson. Whitecap, Toronto. 218 pp., illus. $18.95.

***An orchid flora of Puerto Rico and the Virgin Islands.** 1995. By J. D. Ackerman. New York Botanical Garden, Bronx. 203 pp., illus + map. U.S. $35.

Orquideas Brasileiras em foco. 1994. By R. Agnes. Koeltz Scientific, Konigstein, Germany. 95 pp., illus. cU.S. $54.

Principles and practice of plant conservation. 1995. By D. R. Given. Timber Press, Portland, Oregon. 264 pp., illus. U.S. $39.95.

A revision of the lichen genus *Xanthoparmelis* in South America. 1995. By T. H. Nash III, C. Gries, and J. A. Elix. Cramer, Stuttgart. 157 pp., illus. DM80.

Studies in lichenology with emphasis on chemotaxonomy, geography, and phytochemistry. 1995. Edited by J.-G. Knoph, K. Schrüfer, and H. J. M. Sipman. J. Cramer, Stuttgart. 476 pp., illus. DM180.

***The sunflower family (Asteraceae) of British Columbia, volume II: Astereae, Anthemideae, and Inuleae.** 1995. By G. W. Douglas. Royal British Columbia Museum, Victoria. 382 pp., illus.

Taxonomy of *Eupatorium* section *Verticillata* (Asteraceae). 1995. By E. E. Lamour. New York Botanical Garden, Bronx. 67 pp., illus. U.S.$14.

Environment

Biological degradation and bioremediation of toxic chemicals. 1995. Edited by G. R. Chaudhry. Timber Press, Portland, Oregon. 520 pp., illus. U.S. $69.95.

†A bird-finding guide to Ontario. 1995. By C. E. Goodwin. Revised edition. University of Toronto Press, Toronto. xii+477 pp., illus. $24.95.

Borneo log: the struggle for Sarawak's forests. 1995. By W. W. Bevis. University of Washington Press (Canadian distributor UBC Press, Vancouver). 264 pp., illus. $27.95.

†Canada's biodiversity: the variety of life, its status, economic benefits, conservation costs, and unmet needs. 1995. By T. Mosquin, P. G. Whiting, and D. E. McAllister. Canadian Museum of Nature, Ottawa. xxiv+293 pp., illus. $53.15 in Canada; U.S. $51.50 elsewhere.

1995 conservation directory. 1995.. By National Wildlife Federation, Washington. xxii+501 pp. U.S. $20.

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†Down canyon: a naturalist explores the Colorado River through the Grand Canyon. 1995. By A. H. Zwinger. University of Arizona Press, Tucson. viii+318 pp., illus. Cloth U.S. $35; paper U.S. $16.95.

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Footnote
* assigned for review
† available for review

Index to Volume 109

Compiled by Leslie Durocher

Index to Book Reviews

Botany

Environment

Miscellaneous

Zoology

Advice to Contributors

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

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The **Council of Biology Editors Style Manual**, Fourth edition (1978) available from the American Institute of Biological Sciences, and **The Canadian Style: A Guide to Writing and Editing**, Department of the Secretary of State and Dundurn Press Ltd (1985) are recommended as general guides to contributors but check recent issues (particularly in literature cited) for exceptions in journal format. Either "British" or "American" spellings are acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary** and le **Grand Larousse Encyclopédique** are the authorities for spelling.

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A LIFE WITH BIRDS

Percy A. Taverner, Canadian Ornithologist, 1875-1947

By John Cranmer-Byng

From 1911 to 1942 Percy Taverner was Ornithologist at The National Museum of Natural Sciences in Ottawa, now called The Canadian Museum of Nature. He laid the foundations of scientific ornithology in Canada by building up the necessary collections of birds at the museum, and studying their distribution, working through a network of people who collected specimens and gathered ornithological information from across the country. He was a leading advocate of the need for conservation and wild bird protection, and played a major role, through his research and recommendations, in the creation of a National Park at Point Pelee and bird sanctuaries along the north shore of the Gulf of St. Lawrence and at Percé Rock and Bonaventure Island off the south coast of the Gaspé Peninsula.

Perhaps Taverner's most far-reaching contribution was an educator of public thought. His wide knowledge was passed to the public in his books, *Birds of Eastern Canada* (1919), *Birds of Western Canada* (1926) and *Birds of Canada* (1934). He presented scientific information about his birds in their many plumages and habitats and at the same time conveyed to the reader his own sense of appreciation of the birds he was describing. In this way he helped to make the study of birds and their habitats popular recreation. He was an active council member of the Ottawa Field-Naturalists' Club and an influential Associate Editor and frequent contributor to *The Canadian Field-Naturalist*. Throughout his life and career, his consistent devotion to the study of birds and their behavior, his achievements and difficulties at the National Museum, his bird expeditions to different parts of Canada, and his family life, show a warm-hearted person with a sense of humour who was a tireless writer of letters to his many friends and colleagues.

Additional copies of this Special Issue will be available from the Business Manager, *The Canadian Field-Naturalist*, Box 35069, Westgate P.O., Ont., Canada K1Z 1A2 at a cost of $25.00 (hard cover) or $10.00 (soft cover) plus $2.50 postage and handling.

TABLE OF CONTENTS *(concluded)*

Mailing date of the previous issue 109(3) : 9 January 1996

Articles

Notes

continued on inside back cover

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